BETTER SAMPLING

CONCEPTS
TECHNIQUES
EVALUATION

Y. P. Aggarwal

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Better Sampling : Concepts, Techniques and Evaluation

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PREFACE

The book presents a non-mathematical yet comprehensive survey of the basic principles of sampling. It is an attempt to make available to the research scholars and teachers of various disciplines, a treatment of the subject which can be called intermediate between the very sophisticated and mathematical works like those of Cochran (1972) and Hansen, Hurwitz and Madow (1966) and the sketchy and inadequate treatment presented in the books on research methodology. While the former serve as text books for advanced courses in sampling theory and hence beyond the comprehension of average students of research in various social sciences, the latter are utterly inadequate for making the students sufficiently conversant with the techniques and their applications.

The main emphasis, in this book, has been on the description and critical appraisal of the principles and methods of sampling and their application to various types of problems. Illustrations rather than formulas have been used to clarify the discussion and to aid the intuition. The illustrations have been taken from such diverse fields as education, psychology, sociology, business administration, commerce, economics, forestry and public administration. Hence the book is likely to be useful for students and teachers of research in these fields. A comprehensive bibliography has been given to aid the students in searching out further reading material. Tables of Random Numbers have been added and the method of their use explained fully with illustrations.

The book first appeared under the title *Sampling Methods for Social Investigation*. The content since then has been thoroughly revised, enlarged and enriched. Several new sections have been added to make the book more useful. A number of diagrams have also been given to aid understanding. A scale for self-evaluation of sampling has been devised and incorporated to enable the researchers to have a self assessment of the sampling procedures used by them. In the evaluation of others' research reports also, this tool may be found of great help. A glossary of important terms has also been added.

Grateful indebtedness is expressed to those authors and researchers whose works have been consulted in the preparation of this book and quoted at several places.

Suggestions for the improvement of the book will be gratefully acknowledged.

Y. P. AGGARWAL

CONTENTS

LIST OF FIGURES

1

FUNDAMENTAL NOTIONS OF SAMPLING

THE MAIN purpose of this chapter is to describe the general principles involved in sampling. Very often our attitudes, our knowledge and our actions are based on samples. It applies equally to everyday life and to scientific research. A person's opinion of a bank, or a shop, or an institution is generally based on one or two encounters which he had with it in the course of several years of working with the former. A visitor's opinion about a country after spending a few days in it will be determined by his experiences of a few places he has seen and a few persons he has met. His conclusions about that country will differ from those of a social scientist who spends a number of years in studying the political and the social system of that country and uses the scientific procedures of investigation. Perhaps our visitor is less likely to be aware of the extent of his ignorance. Generally a vaguely formulated understanding of sampling is part and parcel of what is called common sense and is characteristic of everyday approach. However, this common place usage of the term is becoming less informal and unconscious. More and more the informed public, when confronted by the results of a poll or some other conclusion based on sampling procedure, is asking pertinent questions. Who and what type of persons were interviewed ? How many were interviewed ? No longer are such unqualified statements as "Most of the subjects responded negatively," or "over half the juvenile delinquents surveyed came from broken homes" taken as serious scientific propositions.[1]

Now let us view a few more commonplace examples of sampling — the trader-examining a handful of grains from the bag, the tea-taster trying different brands of tea, a technician making a blood-test and a housewife

checking a few grains of rice from the pan to determine whether the entire lot has been properly cooked and become soft. All of them are employing the method of sampling. Their confidence in their judgements rests on the fact that the material they are sampling is so well mixed or homogeneous that the few grains of wheat, a drop of blood, a few leaves of tea or a few grains of rice do adequately represent the whole.

1.1 Population and Sample

A sample is a miniature picture of the entire group or aggregate from which it has been taken. *A sample, in other words, is a smaller representation of a larger whole.* The entire group from which the sample has been taken is known as the "population". The terms "universe" and "supply" are also used but are less popular. The term population, in research, is used in a broader sense than its commonplace meanings as a population of people. A population may consist of persons, objects, attributes, qualities, behaviours of people, answers to various items of a test, the behaviour of inanimate objects such as throws of dice or coins, cities, families, opinions of the electorate of a nation and the like. *A population is a well defined group of any of these. The definition should be explicit enough to permit anyone to say with confidence that a particular object or person is in the defined population and another not. Defining a population means fixing the limits in terms of one or more of its various aspects.* A few of them are described as follows:

1. *Geographical Limits :* A study may be confined to a town, or village, a district, a province, a country or the whole world. The World Surveys of Education[2] conducted by UNESCO include all the countries of the world.
2. *Age or Grade :* A study may include children in the age group 8+ to 10+, or in grades 3 to 5.
3. *Sex and Socio-Economic Status :* The study may be confined to men or women only, or a particular socio-economic status group only.
4. *Physical Attributes :* Just as weight, height, colour of eyes, a particular blood group and the like.
5. *Psycho-Social Behaviour :* Delinquents, neurotic offenders, normals, hospitalized, schizophrenic, unsuccessful or successful candidates in a particular examination, all prize winners in a lottery, recipients of Vir-Chakra and the like.

The selection of one or more of these criteria in defining a population depends on the nature and scope of the research in hand.

Kempthorne[3] has distinguished between "experimentally accessible population" and "target population". The former is the population of subjects that is available to the researcher for his study. The target population is the total group of subjects about whom the researcher is empirically attempting to learn something. For example, a researcher has discovered a new approach to teaching map reading to the 8th class students. Probably he would like to conclude that his method was better for "all 8th class students in India", the target population. However, he randomly selects his sample from all "8th class students in his state", the experimentally accessible population. The experimenter will have to make the following two jumps in his generalization :

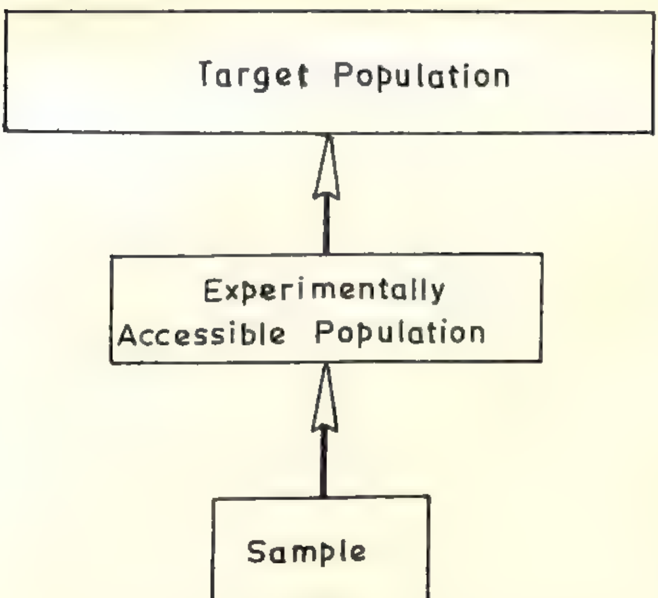

Figure 1.1 Relationship of Sample and Target Population

1. A jump from the sample to the experimentally accessible population, and
2. Another jump from the experimentally accessible population to the target population.

The first jump is justified on the basis of inferential statistics and does not present any problem if the sample has been selected randomly from the experimentally accessible population.

In the above example, if the experimenter has selected his sample randomly from all 8th class students of India, the experimentally accessible population would have been very much like the target population and inference could have been made with greater confidence. If the sample has not been randomly drawn from the accessible population, the generalization with probabilistic rigour would not be possible. In such a situation, the sample becomes the experimentally accessible population. However, some authors like Cornfield and Tukey[4] advocate generalization from the sample to a population "like those observed".

The second jump, from the accessible population to the target population is relatively less justified and lacks rigour as compared to the first jump. The degree of statistical confidence with which an experimenter can generalize the target population is never known because the experimenter is never able to sample randomly from the true target population.

For a further discussion of these concepts the reader is referred to Kempthorne[5] and Bracht and Glass.[6] The population may also be classified as "real", "artificial" and "hypothetical" populations. A real population is one which actually exists. An artificial population is created by the researcher in order to illustrate a principle, or to make for more convenience and ease in carrying out the study of a problematic situation. A hypothetical population is an artificial population devised purely on theoretical basis. This type of population enables the researcher to work with an infinite population of entities, when the real population under study is much smaller. "Simulation" is used for the creation of artificial populations and taking samples out of them.

Populations may also be categorized as "known" and "unknown". In a known population the frequency distribution and/or the parameters (Mean, Mode, Median, SD etc.) are known. A population for which such estimates are not available may be termed as an "unknown population".

However, in most practical research, the populations used are unknown and parameters are computed on random samples.

In cases where the design of research allows for the inclusion of the whole population if it was accessible and also within manageable limits, sampling may not be resorted to and the study conducted on the entire group. However, in studies involving large populations, sampling provides a less expensive, more efficient and quicker method of data collection.

1.2 Advantages of Sampling

The following advantages generally accrue from using a sample rather than the entire population.[7]

Reduced Cost : When data are collected only from a small fraction of the entire population, expenditures are smaller than if the entire group was studied. Surveys sometimes use as small a number as one person in one thousand.

Greater Speed : The volume of the data to be collected will be smaller. Hence it can be collected, tabulated and summarized more quickly with a sample than with the total population. In applied research where urgent answers to certain problems are needed, this aspect gets an added importance.

Greater Scope : In studies where a complete enumeration and census of all units of population are impracticable and the research requires the use of highly trained personnel or specialized equipment, the choice may lie between collecting the information by sampling or abandoning the research itself. The use of the Rorschach, the TAT, the CAT and the Stanford-Binet are some of the instances in which sampling becomes all the more important. Thus surveys using sampling provide greater flexibility and scope.

Greater Accuracy : With the reduction in the volume of work, personnel of higher expertise and training can be employed and a more careful supervision of the field work and processing of the data are possible. Hence sampling may produce results which are more accurate than those which could have been obtained through a complete census. Moreover, sampling is particularly more important in obtaining accurate results about phenomena which are undergoing rapid changes such as opinions about political and social issues.

Mouly[8] has aptly summarized the advantages of sampling in the following words :

> Sampling is both necessary and advantageous. Taking a complete census is generally both costly and difficult ; in many cases it is completely impossible. What is not so clearly recognized by a layman, who feels that one takes a sample when he cannot get a complete census, is that sampling frequently results in more adequate data than a complete census. In an interview study, for example, sampling not only saves money but also permits greater care and control to be asserted; it allows for better training and coordination among the interviewers; it permits greater depth in interviewing; it allows the interviews to be conducted in a relatively short time so that the distorting effects of the passage of time are minimized; it also permits greater depth in analysis and greater accuracy in processing.

Sampling is an essential part of all scientific procedure. It is not merely an adjunct of the social sciences. It is already well developed in biological researches in the field of agriculture. It is also a basic tool in other areas of biology, as well as in physics and chemistry. Science, committed as it is today to the variability of observations in all fields, is forced to sample from a universe of possible observations rather than believing that one observation provides an absolute and immutable truth.

1.3 The Requirements of a Good Sample

There are two basic requirements of a good sample — its representativeness and adequacy.

If information from sample data is to be generalized to a population, it is essential that the sample should be representative of that population. In the strict sense of the term a representative sample would be a miniature or replica ideally in all respects of the population from which it has been drawn. It should apply at least to the characteristics directly under investigation or those likely to affect these characteristics indirectly. But if in order to check the representativeness of a sample, the corresponding characteristics of the population would have to be known, there would, then, be no need to have a sample. Hence in practical use the researcher may seek a random sample rather than necessarily a perfectly representative one. Such a sample will fall within the range of random sampling errors, and will facilitate the estimation of the population parameter on the basis of probability theory.

A good sample not only needs to be representative, it needs also to be adequate or of sufficient size to allow confidence in the stability of its

characteristics.

The research supervisors and advisors are very often asked, "How big a sample do I need?" "Will 200 cases or 500 cases or 5 per cent of the population be sufficient for the study?" The researcher may feel disappointed when told that an accurate answer to his questions was not possible unless he himself provides a good deal of information relating to the study, the population it supposes to cover, the sampling design to be used, the designation of the parameters which he wishes to estimate, the magnitude or range of unreliability of estimates he is ready to accept, a rough estimate of the dispersion of the characteristics unde investigation and the like.

An adequate sample is one that contains enough cases to insure reliable results. Hence planning in advance for the size of the sample is very important. The procedure of determining the sample size required varies with the nature of the characteristic under study and its distribution. However, for the purpose of illustration, a case involving assumptions of random samples based on normal probability distribution is given as follows :

Suppose the researcher has decided (i) to use 95 per cent level of confidence, (ii) that for the purpose of study a 1 per cent error is acceptable; i.e., the sample mean does not differ from the population mean by more than 1 per cent , and (iii) has obtained preliminary estimate of the Standard Deviation of the population which is 10. He can, then use the formula meant for computing the Standard Error of Mean and through an inverse process work out the value of n or sample size.

Formula for $SE_M = \dfrac{\sigma}{\sqrt{n}}$

Value of standard deviate z at 95 per cent level of confidence=1.96

Since the acceptable difference between the sample M and population μ is 1 per cent, the following equation is set up :

$1.96SE_M = 1.00$

$1.96\dfrac{\sigma}{\sqrt{n}} = 1.00$ (substituting the formula given above)

$\sqrt{n} = 1.96\ \sigma$ (by cross multiplication)

$$\sqrt{n} = 1.96 \times 10 \quad \text{(Substituting the value of } \sigma \text{)}$$

$$\sqrt{n} = 19.6$$

$$\sqrt{n} = 384.16 \text{ or } 384$$

Thus 384 cases are required to meet the condition of a 1 per cent error at the 95 per cent confidence. If the researcher decides upon $^1/_2$ per cent error and raises the confidence level to 99 per cent a considerable increase in the sample size will be required. Solve : (2.58 SE (M) = .5). Generally, doubling the precision of a sample statistic calls for quadrupling the sample size. Another observation is also important to make. The size of n is also affected by the size of the standard deviation. The larger the standard deviation the larger the sample required. The smaller the deviation the smaller the sample size. Hence in the case of more homogeneous populations, a relatively smaller size of the sample will be required.

Parten[9] has suggested a similar procedure for planning in advance for size of sample. The formula is

N_s = $(\sigma\ Z/T)^2$ in which

N_s = The required sample size,

σ = a preliminary estimate of standard error units equal to a desired probability, and

T = The permissible tolerance of variation in the sample mean.

Z = The number of standard error units equal to desired probability.

The main hindrance in the use of the above mentioned formulas is the question of obtaining a preliminary estimate of the population standard deviation. To solve this problem the following suggestions are offered for the benefit of the researchers. The population standard deviation may be obtained by

1. Undertaking a pilot study,

2. Looking into the previous research on the subject for such information.
3. Demming suggested the following formulas :

Value of SD in rectangular distributions	=	.29 h
in Symmetrical distributions	=	.24 h
in skewed distributions	=	.21 h

In which h = highest X - Lowest X; or the range.

Hence the size of the sample is determined on the basis of variability of the population, the degree of precision required and the level of confidence at which the results are to be interpreted. However, the adequacy of the size of the sample does not automatically ensure accuracy of results. The sampling and measurement techniques ought to be selected and employed very carefully.

1.4 Bias in Sampling

A sample that is not representative is generally known as a "biased sample". The very adjective "biased" connotes that the sample is not a good one or has been drawn with some prejudices and preferences in the researcher's mind or some of the units in the population have been unduly favoured in selection or others were at a disadvantage. Yule and Kendall[10] have described the sources of bias in samples in the following words :

> Bias may be due to imperfect instruments, the personal qualities of the observer, defective technique, or other causes. Like experimental error, it is difficult to eliminate entirely, but usually may be reduced to relatively small dimensions by taking proper care — Experience has in fact shown that the human being is an extremely poor instrument for the conduct of a random selection. Whenever there is any scope for personal choice or judgement on the part of the observer, bias is almost certain to creep in.

Research in social sciences is replete with studies bearing the more superficial earmarks of erudition and authority that are intrinsically worthless and misleading for the sole reason that they are based on unrepresentative samples. Studies involving data collection through a mailed questionnaire often produce incomplete and distorted returns. A researcher may begin with the first list of the respondents which is a representative one but due to non response, and the operation of other selective factors, he may end up with an extremely biased sample.

It should not be inferred that all the ills and errors in social research are due to biased sampling. Many other sources of error are: the observation techniques, interviewing process, imperfection in the design of the questionnaire, tabulation plans and the processing of the material.

Marks[11] argued in defence of the bias in the following words :

> Another area of serious misconception is the field of bias in sampling. The very term 'bias' suggests that it is undesirable — and it is. There are, however, conditions where it is better to use a biased estimate rather than accept the even more undesirable alternatives necessary to removing the bias. The criterion should be total error, which is composed of bias and variance. If avoiding a small bias means taking a very large variance, take the bias and keep the total error small. Most of our errors of judgement are, however, in the reverse direction i.e., we strive for big samples (which means usually, small variances) and pay no attention to the sizes of the biases. The extremes of attending only to bias or attending only to variance are both undesirable.

Cochran[12] has demonstrated the effect of bias on errors of estimation. In the following diagram the two tails of the curve are affected differently due to bias.

Bias in statistical terms may be defined as :

Bias or β = estimator (μ) - true population value (μ).

The amount of disturbance = β/σ or the ratio of the bias to the standard deviation. It is generally accepted that the effect of the bias on the accuracy of the estimate is negligible if the bias is less than one-tenth of the SD of the estimate.

As already stated - bias enters into sampling chiefly due to the following reasons :

1. Use of non-random techniques.
2. Use of unscientific and careless randomization.
3. Errors of measurement.
4. Non-response and experimental mortality.

1.5 Sampling Errors

Generally data are collected from the sample with the presumption that it was representative of the population. However, data collected from a sample may not be representative of the population. It is possible due to *sampling errors* and/or *measurement errors*. Sampling errors can be further classified into *random errors* and *systematic errors*. Measurement

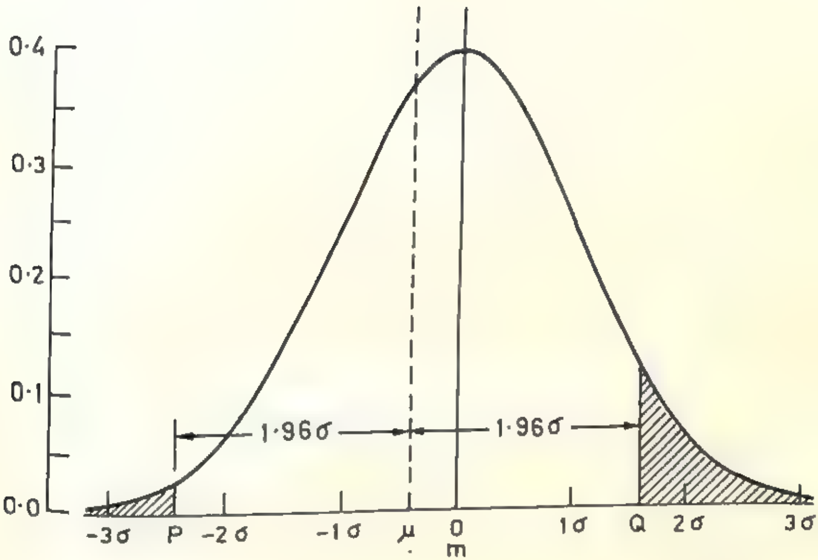

Figure 1.2 Effect of Bias on Errors of Estimation

errors also have a similar classification. The classification of these errors can be better understood with the help of the following diagram :

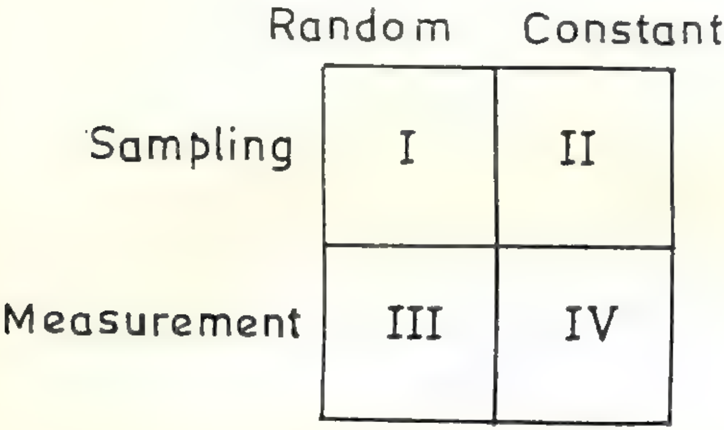

Figure 1.3 Errors of Sampling

Cell I refers to the errors which occur due to sampling fluctuations, and are inherent in the very nature of random sampling. These are unavoidable whenever probability is resorted to. However these errors tend to cancel each other to the point that if n is sizable the sample statistic will get very close to the population parameter. As n increases the size of these errors decreases and becomes zero when n = N. It is also possible to estimate the magnitude of these errors by using a probability model.

Cell II indicates sampling errors which do not cancel out but affect the result in one particular direction. For example if one were to sample the income of university teachers, and select the seniormost teacher from each department, the estimate is bound to be in error in the direction of a higher value. Similarly if one wishes to sample the monthly sales of the shopkeepers in the university market over a year and select the first week of every month, one is sure to end up with wrong estimate because university employees get paid in the first week of every month and hence the sales are the highest then.

This type of errors render the data unfit for any generalization. This is the worst source of bias in sampling which should be avoided.

Cell III Sampling is a tool for another ultimate goal, i.e. of measurement or collection of data or determination of the characteristics of a sample. Hence measurement errors get involved in any sampling results. Random errors of measurement are due to unreliability of the measuring tool. All measuring tools must mismeasure to some extent and be unreliable to that extent. However, repeated measurements on a group of subjects or increase in the size of the sample can lead to self-cancellation of these errors.

Cell IV indicates constant errors of measurement which cannot be eliminated by increasing the size of the sample : these are directional and do not cancel each other. If a weighing machine is in error and gives weight short by one kilogram, it would introduce a systematic tendency on the part of the sample statistic to be higher than what it should be . However, careful planning and periodic checking and validation can be helpful in avoiding these errors. However, systematic errors are generally difficult to detect.

Error reduction by judicious planning

A judicious planning can lead to error reduction and save a lot of expense by using smaller groups.

The Lamarkshire milk experiment[13] in England involved the daily feeding of three-fourths of a pint of raw milk to 5000 children and of an equal amount of pasteurized milk to another group of 5000 over a period of 4 months. These 10, 000 plus a control group of 10,000 were measured for height and weight at the beginning and the end of the 4-month period. The purpose of the experiment was to check at the relative merits of raw vs. pasteurized milk, the control group was non-essential. Despite large numbers the feeder and control groups were not comparable as regards initial heights and weights. The teachers, ignorant about the adverse effects on research, showed a benevolent attitude and gave preference to frail and undernourished children for inclusion in the feeder groups. A carefully supervised random sampling or a definite pairing procedure would have avoided this selective bias. The use of the expensive large samples would have been avoided if, according to "Student", the use of 50 pairs of identical twins had been used. It would have yielded a more precise and accurate information at only 2 per cent of the cost of the original experiment.

1.6 Sampling Designs Classified

Sampling designs can be broadly classified into two categories :

Probability Sampling Designs and

Non-probability Sampling Designs.

The probability designs are based on random selection as the fundamental element of control and permit the specification of the precision that can be obtained and the size of the sample required for that purpose. The non-probability designs are based on the judgement of the investigator as the most important element of control. An investigator may be instructed to interview 100 persons passing a certain market crossing, interview on phone, a specific number of car owners, or housewives. The guiding principles in non-probability designs are : the availability of the subjects, the personal judgement of the interviewer, and the convenience in carrying out a survey.

However, in non-probability designs, there is the risk of over-weightage of the cooperative and the available. Moreover, dependence exclusively on the investigator's insight does not lend the design to any statistical procedure for the purpose of determination of the margin of sampling errors.

It may be possible in some studies to combine the probability and the non-probability procedures but such mixed designs are complicated and beyond the comprehension of an average student.

1.7 The Criteria for Selecting a Sampling Design

Young[14] has suggested three criteria which should be kept in mind while selecting or constructing a sampling design.

1. A measurable or known probability sampling technique should be used so that the risk of errors in the sample estimate can be controlled, the degree of confidence that can be placed in the published figures can be pointed out and whether sufficient resources are available to get results from the sample with the reliability required, can be determined in advance.
2. Simple, straightforward and workable methods adapted to available facilities and personnel should be used.
3. An attempt should be made to achieve maximum reliability of results for each dollar spent. Striking at an optimum balance between expenditures and a maximum of reliable information should be the guiding principle.

Generally it is advisable to conduct a pilot study to uncover potential sources of difficulty, to provide the investigating staff with training in statistical as well as field work, thus ultimately saving time and expense.

1.8 Sampling Frames

A Sampling Frame is generally the list of sampling units from which the sample can be selected at each sampling stage. Indexes, maps and other population records used for the purpose are also included in this definition. Examples of sampling frames are telephone directories, directories of street addresses, electoral rolls, list of publishers of books, lists of schools and colleges in a state, rating records with the local authorities. Sometimes these lists, maps or indexes are in existence and can be readily obtained. Sometimes these have to be prepared at an extra cost before sampling can be effected. Sampling frames are very important and influence every aspect of a sampling design — the population coverage, the stages of sampling, the stratification used and the process of selection itself.

The construction of a list of sampling units or a frame is often one of the major practical problems faced by any surveyor. From bitter experience, the samplers have become very critical of the readily available frames because good frames are hard to come by. Despite assurances from the agency that has constructed the lists, such lists are often found to be inadequate, incomplete, or partly illegible, or to contain an unknown amount of duplication. The problem of inadequacy of a frame arises when it does not cover the whole of the population to be surveyed. A frame may be inadequate for one purpose and quite adequate for another. A frame is incomplete when some of the population members who are supposed to be on it are in fact not on it. Since these elements will have no chance of being selected, the sample will be unrepresentative of the population to that extent.

Another problem from the use of sampling frames arises when the sampling units are listed in clusters and not individually. For instance, if a sample of individual teachers of primary schools in a state is to be taken, and only a list of primary schools and not of teachers is available, selection by individual units will not be possible. Cluster sampling in which all elements in the selected clusters are taken may not always be a good procedure especially when clusters are too large and contamination of responses is possible due to communication among the elements of a cluster.

Blanks and foreign elements in a frame also create problems. Some lists are out of date because some people have died, or emigrated or left the defined survey population in some way. A sampling frame may have wider coverage than survey population. For instance, in a survey of government school teachers with post-graduate qualifications, the list of teachers may include those teachers also who do not possess such qualifications. A high proportion of blanks and ineligible elements in a sampling frame may lead to serious difficulties in sampling.

Duplication of elements leads to some of the elements having greater chance of being selected for the sample. In cases where a sampling frame has been constructed through a combination of lists having overlapping membership, this problem is very likely to arise. It may arise in other ways also. The name of the owner of four houses, each in a different street may appear four times at different places in the list of house owners of that town.

The requirements of a good sampling frame are — adequacy, completeness, absence of blanks and foreign elements, and absence of duplication. These are, no doubt, stringent and no actual frame meets them all. The sample designer has to be cautious about the limitations of the frames made available to him. In case these do not enable him to sample his population completely, accurately and conveniently, he may construct his own.

1.9 Some Other Important Concepts

Probability sampling is based on some important statistical concepts. The most important among them is the law of large numbers.

Law of Large Numbers

The law of large numbers states that, as the sample size becomes large, the probability that an estimate will differ much from the parameter it estimates becomes small. In symbolic terms : "If μ is a parameter, ξ is a sensible estimator of μ obtained from a probability sample size n and ξ is any positive number, then the law of large number states ; $P(1\xi - \mu 1 > \delta)$ decreases towards zero as n increases towards infinity."

The δ is a small number that is used to make a general statement about the size of the difference between ξ and μ.

It is intuitively obvious that a larger number provides a more precise estimate of a parameter than a small one. However, one precaution must be taken. Large n does not automatically guarantee representativeness

unless the estimator is a sensible one. For example, average salary of 1000 senior industrialist executives probably would not give a more accurate estimate of national average income than the average salary of 100 randomly selected adult citizens. Hence, the average salary of senior industrial executives is not a sensible estimator for the purpose of estimating the national average income. Look at other examples. :

The average salary of 1000 University Professors is not a good estimator as compared to the average salary of 100 randomly selected teachers (including professors) for estimating the average salary of a teacher in a country.

The average salary of 1000 bank managers is not a good estimator as compared to the average salary of 100 randomly selected bank employees (including managers) to estimate the average salary of a bank employee.

The reader may think of more examples which can be picked up from various fields and subjects : If the smallest or the largest value is taken, it is not a sensible estimator.

Another concept, important to sampling is the concept of an unbiased estimator. If an estimator satisfies the condition that the average of its sampling distribution shall be equal to the true parameter value, it can be said to be an unbiased estimator.

Central Limit Theorem and the Normal Distribution

It is presumed that the researcher is aware of the concept of sampling distribution. However, for refreshing his knowledge we may define sampling distribution as the distribution of a statistic (like mean or variance) generated by calculating a large number of these randomly selected samples from the same population.

It is an astounding fact that not only a particular sampling distribution approaches some regular form as sample size increases, but that it is always the same form, the so-called normal distribution. The central limit theorem is a complete generality of this mathematical result that the form of the population from which we are sampling makes no difference provided that -

(i) The more irregular the distribution in the population, the larger the sample size we require.

(ii) Random sampling is undertaken for the purpose of inference.

Random sampling tends to remove biases and enables us to estimate unbiasedly. It allows for the estimation of precision of our estimator from

the same sample.

The central limit results apply not only to sample average, but to practically all the estimators (like variance).

1.10 A Generalized Model of Sampling

Sampling has the important objective of helping the researcher in producing good research. However, there is a constant interplay between the objectives and strategies of research adopted and the strategy of sampling to be utilized. Very often the former gets an upper hand. In the process of sampling, many decisions are to be taken at several stages. The following diagram outlines the process of these decisions, while selecting a sampling strategy. It also presents, in a nutshell, a generalized model of sampling from which a sampling strategy required for a particular research design can be selected.

Three important constraints which are faced by an investigator while selecting a sampling strategy are :

1. Objectives of the study.
2. Type of the study.
3. Resources available for the study.

If the objective of research is to confine the application of the results of the study to a small local group, sampling may not be given as much consideration as in a study whose results are to be applied to a larger group. Action research generally does not require sampling from larger groups. Definition of the target population and the experimental unit is very important in the latter case. Survey studies generally have a more rigorous sampling, as these are concerned with very large groups and populations. In experimental studies, the internal validity (control of sources of error which may confound the interpretation of results) is of greater concern as compared to the external validity (generalizability of results over other groups, situations etc.. Sampling is also not very essential in historical research except when one intends to sample sources of historical evidence which is rarely done. The availability of time, funds, manpower and equipment required is another important consideration in deciding about the size and technique of sampling.

The decision whether a probability design or a non-probability design is to be applied also rests on the three important constraints mentioned above. If one is interested in obtaining an estimate of the sampling error, one may resort to probability sampling rather than a non-probability one.

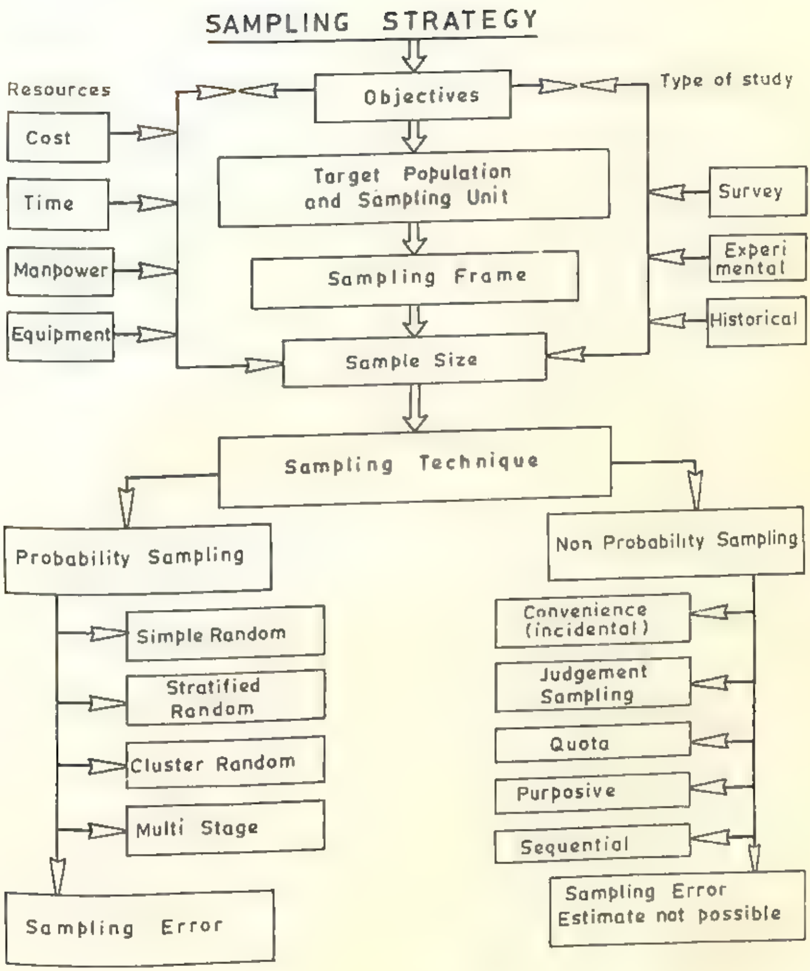

Fig 1.4 A Generalized Model of Sampling

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Important New Ideas

SAMPLE
SAMPLING FRAME
POPULATION
TARGET POPULATION
EXPERIMENTALLY
ACCESSIBLE POPULATION
FINITE POPULATION
LAW OF LARGE NUMBERS
NORMAL DISTRIBUTION
RANDOM SELECTION
ARTIFICIAL POPULATION
HYPOTHETICAL POPULATION
SAMPLE SIZE
BIAS
SAMPLING ERRORS
MEASUREMENT ERRORS
PROBABILITY SAMPLING
NON-PROBABILITY SAMPLING
ESTIMATOR
CENTRAL LIMIT THEOREM

2

SIMPLE RANDOM SAMPLING

2.1 The Technique

SAMPLE studies deal with samples drawn from finite populations or populations which contain a finite number, N, of units. If these units can all be distinguished from one another, the number of distinct samples of size n that can be drawn from the N units is given by the combinatorial formula :[1]

$$\binom{N}{n} = {}_{N}C\,n = \frac{N\,!}{n\,!\,(N-n)\,!}$$

For illustration, if a population contains 4 units denoted by **A, B, C** and D, there are six different samples of size 2, as below :-

AB AC AD BC BD CD

In fixing these combinations, the same letter is not repeated in any sample and the order of the occurrence of the letter has been ignored. For example, AB and BA are identical and so are AC and CA, and AD and DA.

Simple random, sampling, theoretically, is a method of selecting n units out of the N units in such a way that everyone of the ${}_{N}Cn$ samples has an equal chance of being selected. In practice, however, a simple random sample is drawn unit by unit through the following steps of procedure :

The first step which is common to all types of sampling designs is the definition of the population by specifying its various limits. It is followed by the preparation or procurement of the sampling frame. One special requirement of simple random selection design, at this stage, is that the sampling frame should incorporate the names or serial numbers of

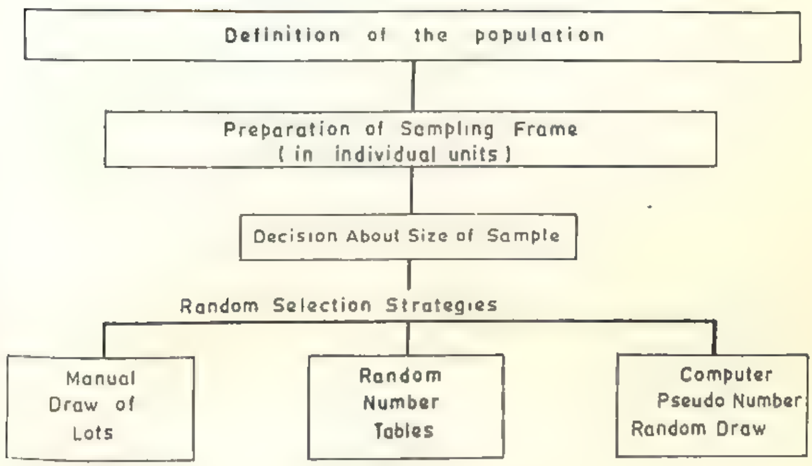

Figure 2.1 The Process of Simple Random Selection.

individual units and not of clusters or groups. For example, if the experimental unit is a student, list up all the individual students and not simply classrooms or schools. If the study is to be conducted on households, list up all the households and not blocks or sectors. Generally the researcher need not be concerned as to how or in what order the population elements have been arranged in the sampling frame. The order — high magnitude to low magnitude or reverse; first come first listed; — will not make any difference as the representativeness of the sample will be taken care of by the randomization process. A decision about the size of the sample should be based on the considerations already mentioned in Chapter I. However, samples on human beings should be fairly large so as to ensure reliability of results. A sample of less than 30 units based on random selection will generally be dubious in terms of its representativeness.

For drawing up a random sample, we need some physical operation, some practical procedure which would reasonably fit into the probability model that underlies our probability theory. Generally the procedures require "tossing perfect coins", drawing "perfect discs from perfect urns", or "drawing perfect balls from perfect urns after complete mixing." This provides an intuitive grasp of the kind of physical process necessary for the purpose. Perfect coins, balls, discs, and urns, hint at the unbiasedness of these things and 'complete mixing', at the randomness of the population.

However, there are some serious objections to these procedures. The objects may not be such as could be mixed. The elements will have to be numbered. The numbers will then be mixed and drawn. The objects or elements bearing those identification numbers will then be picked up for inclusion in the sample.

Another objection is that it is difficult to construct perfect coins, perfect balls, perfect discs, and perfect urns.

Thirdly, the condition of "well mixed" may not be attained despite all efforts, and thus the principle of randomness in the population may be violated. Hence we should use the equivalent of this procedure already performed by careful experts for us and results presented in tables of random numbers - our convenient equivalent of complete mixing of perfect balls, perfect discs and perfect coins in perfect urns. Hence the researcher is advised to use the random number tables instead of lottery method. The tables have already been referred to above. For samples

involving n's running into thousands, and having large sampling frames, the use of random numbers or manual lot-drawing will be too cumbersome to recommend. In such situations, computer generated random selection should be resorted to, to cut down on the time and labour involved in other methods.

2.2 The Tables of Random Numbers

Tables of random numbers have been prepared by Kendall and Smith,[2] Fisher and Yates,[3] and Tippett,[4] and constitute a very convenient and most objective method of random selection. From the members of population already numbered from 1 to N, the required number of units are selected from one of these tables in any convenient and systematic way. For tables of random numbers and guidelines about their use see Appendix. These tables are so prepared that all the ten numbers from 0-9 have an equal chance of being selected. If we examine these tables, we will see that whether we go down a column or across a row, there is no discernible pattern. The numbers are computer generated and are truly random. If we count up the number of O's, 1's, 2's etc., from any of these tables, one will notice that their number is approximately equal. Students may generate their own tables of random digits by using ordinary lottery method on the ten digits - 0 to 9 - and listing up the numerals drawn each time. However, this is unnecessary keeping in view the fact that these tables are readily available in any book on statistics on sampling theory.

2.3 Sampling Without Replacement

The method and formula given in the beginning of this section pertains to sampling without replacement where a unit drawn is not put back or replaced in the population before another unit is drawn. Thus the size of the population does not remain the same with every unit drawn. The table given below makes it amply clear :

Table - 2.1

Relationship of the Element Position to Number of Choices and Probability in Sampling without Replacement

Position of element in the sample	Number of choices (possible)	Probability
Ist	N	1/N
2nd	N-1	1/(N-1)
3rd	N-2	1/(N-2)
-	-	-
-	-	-
-	-	-
-	-	-
	-	-
(n-1)th	N-n+2	1/(N-n+2)
nth	N-n+1	1/(N-n+1)

Two important things need be noted. In sampling without replacement, with the drawing of every unit, the possible number of choices goes on decreasing by one every time, thus implying that every time we are sampling from a population of different size. Secondly, the probability of selection of every unit drawn is different, although known. In a population of 100, the first unit to be drawn has 100 choices and a p of 1/100; the second unit to be drawn has 99 choices and a p of 1/99, and so on. However, the method of random sampling is based on the assumption that all $_N$Cn samples have an equal probability and it is easy to verify also.

2.4 Sampling with Replacement

In sampling with replacement or unrestricted random sampling a unit that has been drawn, is put back or replaced in the bowl or urn or the list, and can be drawn again and reappear more than once in the same sample. Suppose that a sample of n=3 is to be drawn from the population of four units — A,B,C and D — using the method of sampling with replacement. The possible groups or samples will be:

AAA	BBB	CCC	DDD
AAB	AAC	AAD	ABB
BBC	BBD	ACC	BCC
CCD	ADD	BDD	CDD
ABC	ABD	ACD	BCD

Thus by enumeration we arrived at 20 possible groups with no two groups being identical. The number of possible groups of size n from a population of N units, using the method of sampling with replacement is given by the formula :

$$\frac{(N+n-1)!}{n!(N-1)!}$$

In the above problem the number of possible groups as given by the formula is :

$$\frac{(4+3-1)!}{3!(4-1)!} = \frac{6\,!}{3! \times 3!} = \frac{720}{6x6} = 20$$

(checks with those enumerated above)

Sampling with replacement is entirely feasible but except in special circumstances, is seldom used. There seems little justification in having the same unit twice in the sample.

In sampling with replacement the number of possible choices and the probability of the selection of each item, regardless of what elements have been drawn previously, remain the same for each item. The table given below shows this relationship.

Table - 2.2

Relationship of the Element Position to Number of Choices and Probability in Sampling with Replacement, N= 100 and n = 10

Position of element in the sample	Number of choices (possible)	Probability
Ist	10	1/10
2nd	100	1/100
3rd	100	1/100
-	-	-
-	-	-
-	-	-
9th	100	1/100
10th	100	1/100

The method of random selection with replacement cannot be conveniently used and serious practical difficulties may be experienced in the following types of situations:

(1) When the population is very large;

(ii) When the population is not finite, the method becomes theoretically inapplicable;

(iii) When the nature of units is such that once a unit is drawn it dies or is destroyed and cannot be put back in the aggregate;

(iv) When samples of mutually exclusive units are required to satisfy the experimental design or the statistical design of the analyses.

When a population contains a large number of units and the sample size is small, formulae for sampling with and without replacement yield very similar results. For example, a sample of size 2 may be taken from a population of 1000 in $N^n = 1000^2 = 1000,000$ ways using sampling with replacement; and in $(N)_n = 1000 \times 999 = 999000$ ways when sampling without replacement. The latter figure is only 0.1 per cent smaller than the former.

Before concluding this introduction to sampling with replacement, three additional remarks can be offered.[5] Firstly, when sampling with replacement, it is possible for the sample size to be greater than the population size and still not have observed every unit in the finite

population. This cannot occur when sampling without replacement. Secondly, the variance of the mean when sampling with replacement is already larger than when sampling without replacement. Thirdly, in the more mathematical presentations of statistical methods, discussion of sampling with replacement is much more common than sampling without replacement. There are at least two reasons for this. One is that it is popular to assume that the sampled population is infinite in size. The other is that sampling with replacement is associated with more tractable mathematics.

2.5 Terminology Used

In the preceding pages a clear distinction between the terms random sampling without replacement and random sampling with replacement has been made. However, due to the emergence in literature of no standard terminology to distinguish the two, a looseness in their use has been noticed. Kish[6] uses "Simple random sampling" for the former and "Unrestricted random sampling" for the latter. Cochran[7] also uses "simple random sampling" for sampling without replacement, but suggests that "unrestricted random sampling" is just an alternative phrase for "simple random sampling". Yule and Kendall[8] use "simple sampling" to mean sampling with replacement. In the present work the author has also followed Kish.

2.6 Concluding Remarks

The foregoing discussion would remove the layman's misconceptions of random selection as something haphazard, careless, unplanned, hit and miss and something involving exercise of no conscious selection on the part of the investigator. Such ideas are far from correct. However, simple random sampling is the simplest probability design calling for no special expertise and training or even insight. It can be used mechanically by anybody who has all the population elements listed and a set of tables of random numbers.

At the same time, it allows for the control of sampling error. But a randomly chosen sample may look most "unrandom". If a sample, by chance, contains no woman although there may be a fair proportion of women in the population, the sample is unrepresentative of the population and hence cannot reflect its true characteristics. But such "extraordinarily unlikely" events may occur, such a sample being close to the tails of the sampling distribution. If the investigator goes on taking large number of

such samples in precisely the same way, on the average, the estimates of the characteristics derived from them all would correspond to the true characteristics in the population.

The unrepresentativeness of a single sample does not throw doubt on the randomness of the sampling procedure. In cases where reoccurrence of such "unrepresentative looking" samples is detected, the investigator will have grounds for suspicion and will be well advised to review the procedures of sampling used by him. It may, however, be understood that the randomness of the process can be gauged by studying the results of repeated samples, not by the appearance of a single one.

Before concluding the discussion on simple random method, it would be appropriate to mention the precautions necessary to avoid inadvertent departures from randomness :

1. The definition of the population and of the observations should be precise and coinciding with each other.
2. The definition or list of all the population elements should be complete.
3. The mechanical procedure of drawing the sample should be easy to carry out and should not allow any biases to enter.[7]

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Important New Ideas

SIMPLE RANDOM SAMPLING
SAMPLING WITH REPLACEMENT
SAMPLING WITHOUT REPLACEMENT
UNRESTRICTED RANDOM SAMPLING
EXPERIMENTAL UNIT
RANDOM NUMBERS

3

SYSTEMATIC SAMPLING

3.1 The Technique

INSTEAD of going through the laborious process of choosing randomly from a list that is not necessarily assumed to be random (as in random sampling), it would be much simpler if we could assume the units to be randomly listed in the sampling frame and then choose 1/Kth of them with K being any constant.

Thus a variation of the random process of sampling is the systematic selection of the required number of elements of the population to be included in the sample. The process involves the following steps :

1. List up the population elements in some order - alphabetical, seniority, street and house number and the like.
2. Determine the desired sampling fraction, say 100 out of 1000; and also $K = \frac{N}{n} = \frac{1000}{100} = 10$.
3. Starting with a randomly chosen number between 1 and k, both, inclusive, select every kth element from the list. If in the above example the randomly chosen first member of the sample is 5, the sample will be composed of the following: 5th, 15th, 25th, 35th, 45th, 55th, 65th, 75th, 85th, 95th. ...995th elements of the list. Since the elements are chosen from regular intervals, the technique is also known as "Sampling by Regular intervals", "Sampling by Fixed Intervals" and "Sampling by Every kth Unit ".

3.2 Systematic Compared with Simple Random

The procedure of systematic selection is easier and more convenient than the simple random sampling. It provides a more even spread of the sample over the population list and hence leads to greater precision. But, can we consider systematic sampling to be equivalent to simple random

sampling? Strictly speaking, systematic sampling is not equivalent to simple random sampling except in cases where the population list is in a random order. But generally ordinary lists are not so. Order the list on any basis, or get hold of any list already prepared, there is invariably some systematic arrangement. Furthermore, the choosing of the first number randomly does not make it so. It does not provide all the possible samples of size n an equal chance of being selected. Moreover, the random selection of the starting points determines the other units of the sample, hence the whole sample.

This dependence or linkage of one member of the sample on the previous one, makes the process different from simple random method, in which selection of every member is independent of the other.

Moser and Kalton[1] have used the term Quasi-random sampling for systematic samples selected from lists arranged more or less at random or when the feature, on the basis of which it is arranged, is not related to the subject of the survey. The selection at regular intervals, from such a list, can be considered as approximately equivalent to simple random sampling.

Cochran[2] mentions the advantages of systematic sampling over simple random sampling in the following words :

1. It is easy to draw a sample and often easier to execute without mistakes. This is a particular advantage when the drawing is done in the field. Even when drawing is done in an office there may be a substantial saving in time. For instance, if units are described on cards that are all of the same size and lie in a file drawer, a card can be drawn out every inch along the file as measured by a ruler. This procedure is speedy, where as simple random sampling would be slow. Of course, this method departs slightly from the strict " every kth" rule.
2. Intuitively, systematic sampling seems likely to be more precise than simple random sampling. In effect it stratifies the population into n strata, which consist of the first k units, the second k units and so on. We might, therefore, expect the systematic sample to be about as precise as the corresponding stratified random sample with one unit per stratum. The difference is that with the systematic sample the units occur at the same relative position in the stratum, whereas with the stratified random sample the position in the stratum is determined separately by randomization within each stratum. The systematic sample is spread more evenly over the population, and this fact

sometimes made systematic sampling considerably more precise than stratified random sampling.

The relative position of units selected through systematic sampling and those through stratified random sampling is shown in the diagram given below :

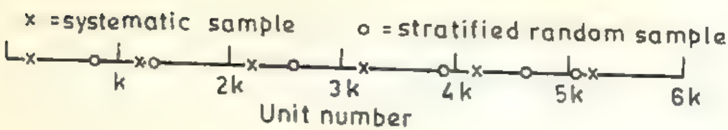

Figure 3.1 Relative position of units selected through systematic and stratified random sampling

The figure given above shows that the relative position of a unit selected from each k through systematic sampling remains the same. But the relative position of a unit selected from each of the strata through stratified random sampling does not remain the same except in a few strata out of a large number of them. In the latter type of sampling, the relative position of a unit in each stratum is determined separately by randomization within the stratum.

All things being equal, simple random sampling is to be preferred for accuracy over systematic sampling. That is systematic sampling may be viewed as a practical approximation to random sampling. While random sampling has the advantage of being accurate (if done properly) and does not require the assumption of a randomized sampling frame, systematic sampling is more practical in that it is less work and thus provides more information per dollar. Also, because it is simpler to perform (especially for inexperienced survey workers), it may reduce error. In general the more complex the method, the greater the opportunity for error. [3]

3.3 Periodic Effect

There is one risk. When the list has a periodic arrangement and the sample interval coincides with the periodic interval or multiple of it, a systematic sample will yield poor results. From a list of married couples listed in pairs with the husband first, a systematic sample, with k = 2, and 1 as the randomly selected first member, will comprise all husbands only. If the starting number is 2, all wives with the exclusion of husbands will be selected.

Some populations have a kind of periodic effect which is implicit and not so obvious. A monthly pay-roll of teachers in a school may always list the teachers in the same order. If only one name is to be drawn over a number of months, the sample may consist mainly of the salary figures of one teacher or two or three teachers. In such cases a simple or stratified random sampling is preferable. Madow[4], Milne[5] and Finney[6] have shown that in some natural populations, some quasi-periodic variation may be present that would be difficult to anticipate. The effect of quasi-periodicity is that systematic sampling performs poorly at some values of n and particularly well at others. Sometimes the process of measurement may introduce this effect.

Populations with more or less definite periodic trend are not so uncommon to find. Students' attendance at a residential university over six working days of the week, flow of road traffic past a particular point

on a road over 24 hours, sales over four weeks of the month of a grocery store having a majority of monthly paid salaried customers, and the number of hours the students spend in study during different terms of an academic year in a system depending on promotions on the basis of one final examination towards the end will show periodic trend.

According to Cochran Periodic trend may take the shape of a sine curve* as shown below :

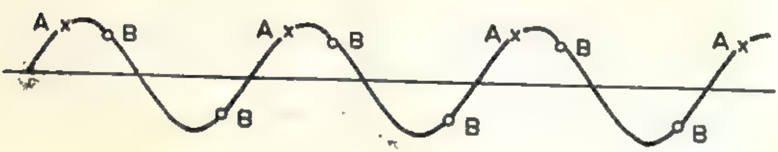

Figure 3.2 Sine Curve showing periodic effect

* A sine curve is a curve which changes in magnitude continuously and in direction periodically.

In such situations effectiveness of the systematic sample depends on the value of K. In Figure 3.2 above the height of the curve is the observation yi. The sample points A represent the case least favourable to the systematic sample. This case holds whenever K is equal to the period of the sine curve or is an integral multiple of the period. Every observation within the systematic sample is exactly the same, so that the sample is no more precise than a single observation taken at random from the population. The most favourable case is B. It occurs when K is an odd multiple of the half period. Every systematic sample, in this case, has a mean exactly equal to the true population mean, since successive deviations above and below the middle line cancel. Between these two cases the sample has various degrees of effectiveness depending on the relation between k and the wavelength.

Hence the performance of systematic sampling in comparison with that of simple random or stratified random is to a great extent dependent on the properties of the population.

Another limitation of the systematic sampling emerges from the fact that very often n is not an integral multiple of k. This leads to samples from the same finite population varying by one unit in size. With N = 33, k = 5, the size of the various possible samples would be as under :

Table - 3.1

The Possible Systematic Samples with Their Size (N=33, k=5)

Sample	Starting Number	Numbers Chosen							Size
i	1	1	6	11	16	21	26	31	7
ii	2	2	7	12	17	22	27	32	7
iii	3	3	8	13	18	23	28	33	7
iv	4	4	9	14	19	24	29		6
v	5	5	10	15	20	25	30		6

The first three samples have n=7, while the last two, n=6. This fact introduces a disturbance into the theory of systematic sampling especially when n is small. However, in samples of size 50 and more, this disturbance may be negligible.

A variation of the systematic sampling is to choose each unit at or near the centre of the stratum. Thus, instead of following the popular method of starting the sequence by a random number chosen between 1 and k, the sampler takes the starting number as (k+1)/2 if k is odd and either k/2 or (k+2)/2 if k is even. Logically this procedure is defensible because in cases of continuous variables, there are grounds for expecting the centrally located sample to be more precise than the one randomly located. However no research evidence has been brought to bear upon the efficacy of centrally located samples.

3.4 Some Practical Hints

1. Use a random start.
2. In case of a very large sample, change the random start several times to avoid trends or periodic fluctuations.
3. Shuffle the list thoroughly.
4. As far as possible have a sampling frame already arranged randomly.

   These precautions will introduce the element of randomization in sampling based on systematic selection.

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Important New Ideas

SYSTEMATIC SAMPLING
PERIODIC EFFECT
SAMPLING BY REGULAR INTERVALS
QUASI PERIODICITY
SAMPLING BY FIXED INTERVALS
SAMPLING BY EVERY Kth UNIT
SINE CURVE

4

STRATIFIED SAMPLING

4.1 The Technique

IN A PREVIOUS chapter simple random sampling technique was explained as the one basic to many other sampling techniques. It was also pointed out that the precision of a simple random sample can be raised by increasing its size. However, it is not the only way. A very popular method to increase the precision is stratification of the main population into a number of sub-populations each of which is homogeneous with respect to one or more characteristics and then to select randomly the required number of cases from each sub-population.

In symbolic terms the population of N units is divided into sub-populations of $N_1, N_2, N_3 ... N_L$, units respectively. The sub-populations are called strata. These sub-populations are non-overlapping and together comprise the whole of population so that

$$N_1 + N_2 + N_3 + ... + N_L = N$$

A sample is then drawn from each sub-population independently of other sub-populations. This may involve random, systematic or any other mode of selection. If sampling from each stratum is done randomly the method can be designated as "stratified random sampling". If systematic sampling is used, it may be called "stratified systematic sampling." The latter is not equivalent to the former. At the most, it can be called "stratified Quasi-random sampling". However, stratification does improve the efficiency of both the random selection and the systematic selection.

The steps involved in the stratified random sampling are enumerated below:

1. Decide upon the relevant stratification factors as sex, residence, age, courses of studies etc.
2. Divide the entire population in sub-populations based on the stratification criteria.

3. List up the units separately in each sub-population.
4. Select the requisite number of units from each sub-population by using an appropriate random selection technique.
5. All the sub-samples thus selected make up the main sample.

4.2 Stratification Criteria

There are various factors on which stratification is often done. Selection of these factors depends upon the nature of the study, the various dimensions included and the nature of the population to be used for the purpose. The factors commonly used for the purpose are : sex, age, income, heights, weights, educational status, I.Q., residence, volume of business, number of employees, strength of students, courses of studies, grade, caste, cultural level, religion and the like.

However, there are three essential requirements for the selection of criteria of stratification. *Firstly*, the criteria for division of population into strata should be correlated with the variable being studies. In a survey of achievement in Mathematics of a particular age group of students, the colour of the eyes - black, brown, blue etc. - or the weights of the students cannot be considered to be appropriate criteria for stratification because these variables do not have any known relationship with achievement in Mathematics. However, the educational level and the economic level of the parents may become logical bases of stratification. *Secondly*, the criteria should be practical. These should not provide so many sub-samples as to increase the size of the required sample over that required by simple random technique. For example, in a study of fertility rates in the population of a small town with population around ten thousand, race, religion, education, socio-economic-status and age have been considered to be appropriate criteria for stratification. Furthermore, if there are three categories of race, two of religion, three of education, three of socio-economic status and four of age, the number of strata would equal 3x3x3x3x4 or 324. Since a statistically satisfactory number in the smallest cell could not be less than ten cases, the minimum number of cases thus required would be 3,240 which will be considered enormous for the small town. Hence the precision gained through stratification will be neutralized by higher costs of data collection. However, this observation applies to surveys in which only overall estimates are to be made. If estimates are wanted also for all the sub-divisions of the population, the argument for a larger number of strata is stronger. *Thirdly*, a good measure of the stratification criteria should be available. If no

reliable and valid tool of assessing socio-economic status was available or categorization into distinct races was not clearly feasible these criteria would lead to confounding of the results.

To solve the dilemma between the number of criteria and the unmanageable increase in the sample size required, it may be assumed, on sound grounds, that many such variables occur as associated factors. In this way, socio-economic status may be chosen to stand also for education and in some cases for religion. In case, the community is fairly homogeneous on race, this criterion can also be kept out in stratification.

When sampling is stratified the Standard Error formula for the mean differs from the Standard Error formula in simple random sampling. The SE_M in this case will be :

$$SE_M = \sqrt{\frac{\sigma^2 - \sigma_s^2}{N}} \quad \text{in which}$$

σ = Standard deviation of the entire sample

σ_s = Standard deviation of the various strata means around the mean of the entire sample.

The standard deviation of the means of the strata around the mean of the entire group can be calculated through the following formula which is just an extension of the usual SD formula :

$$\sigma_s = \sqrt{\frac{N_1 (M_1-M)^2 + N_2(M_2-M)^2 + \ldots N_K (M_K-M)^2}{N}}$$

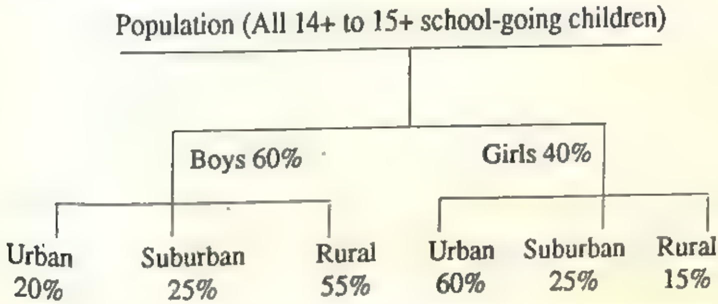
where $N_1, N_2 \ldots N_K$ stand for the number of cases in strata 1 to k; and N and M denote the size and mean of the whole sample.

4.3 The Problem of Proportionality

When the strata have already been constructed and the population divided into sub-populations, the question arises whether an equal number of cases is to be taken from each stratum. In other words, whether an equal weightage is to be given to every sub-sample, or a proportional weightage is, what is desired. The most popular and widely used procedure is to select from each stratum in proportion to the contribution which that stratum makes to the total population. This can be checked from the census records

or other reliable sources of descriptive data.

For the purpose of illustration, suppose a survey of general intelligence of school-going children of the age group 14+ to 15+ in a district is to be carried out. The relevant stratification criteria are - sex and residence (Urban, Suburban and Rural). The school census data of the district show the following percentages of each category in the population of 14+ to 15+ school going children :



Suppose further that a sample of 1000 has been considered to be adequate for the purpose. The distribution of various strata in the final sample will then be as follows :-

Urban Boys	120	Urban Girls	240
Suburban Boys	150	Suburban Girls	100
Rural Boys	330	Rural Girls	60
Total Boys	600	Total Girls	400

Fig. 4.1 Proportional Stratified Sampling

In this way, the stratified proportional random sampling requires selection of units at random from each stratum in proportion to the actual size of the group in the total population.

Stratification, if done wisely, improves the representativeness of the sample. The proportional weighting of each criterion improves it further and an investigator may use a smaller sample and achieve higher efficiency at reduced costs.

4.4 The Optimum Allocation

There are circumstances when disproportionate numbers are drawn from various strata. In cases where a special interest is attached to either the difference between two or more particular strata or upon intensive analysis of one stratum, disproportionate sampling may be used. The results are proportionately reduced at the time of tabulation of data for the whole sample. Situations may arise in which some sub-populations are much more variable than others. It may be due to the fact that the members in those sub-populations are less mixed or variable with respect to the characteristic or attribute of interest and hence are more difficult to represent by a sample of given size. Hence for the purpose of increasing overall precision, a larger sampling fraction may be taken from such a stratum.

Another important consideration is the cost per sampling unit. If the cost per sampling unit (travelling costs and measurement costs) in a particular stratum is greater than in others, a smaller fraction may be taken in costlier stratum. These considerations give rise to the idea and concept of optimum allocation in various strata. For further study of the subject the reader is referred to Kish,[1] Yates,[2] Neyman,[3] Cochran[4] and Stuart[5], who have given various theorems and their proofs.

However, for the purpose of general understanding the following principles concerning disproportionate stratified sampling may be kept in view :

In a given stratum, take a larger sample if :

(i) The stratum is larger,
(ii) The stratum is more variable internally, and
(iii) Sampling is cheaper in the stratum.

However, there are some problems in the practicability of optimum allocation. The investigator generally does not know, before hand, the relative variability and the relative costs in the strata. Moser and Kalton[6] suggest the following ways of overcoming such limitations :

(i) Obtain guidance from the previous surveys using the same or similar populations,
(ii) Ascertain the estimates of standard deviation and cost through a pilot survey,
(iii) If the strata standard deviations are difficult to estimate directly, relate the sampling fractions to some other measurement (strata

means) which is itself known or expected to be related to the standard deviations, and

(iv) Use expert judgement.

However, all these methods produce approximations rather than exact figures, but these may be sufficient, because small departures from the optimum allocation lead to only a slight loss of precision. Moser and Kalton[7] further state, "If the sampling fractions are close to the 'best fractions', there is still likely to be as much of gain as if the best fractions had been used."

Another issue in stratification that needs attention is the problem of optimum allocation in two-way stratification with small samples. The problem becomes all the more difficult if the size of the sample (n) is less than the product of the levels of the two strata. For instance, if there are five levels of income and three levels of residence, the question of selecting a sample of size 10 will pose certain problems. Bryant, Hartley and Jessen[8] have developed a simple technique which requires that the size of sample exceeds the greater of the number of levels of the two criteria. In the case mentioned above, n=10 exceeds the number of levels of income i.e. 4, thus permitting the use of the technique. The method involves arranging of the population in a two-way stratification table and allows approximately equal chance of selection to each unit, at the same time giving each marginal class its proportional representation. For further details of the technique consult Cochran.[9]

Goodman and Kish[10] have suggested another method called "controlled selection" which can be used efficiently even if a substantial number of cells are empty. In this method, the rows represent the principal stratification, one unit being drawn from each row. They have demonstrated the technique which involves finding a limited number of acceptable allocations, each with its appropriate probability, such that cells are selected with equal probabilities.

4.5 Stratification after Selection

In some studies stratification may not be possible before the data have been collected. The stratum to which a unit belongs may not be known until the investigator has actually gone in the field to conduct the survey. Personal characteristics such as sex, race, educational level, age are examples of such stratification criteria. The procedure involves taking of a simple random sample of the required size and then classifying the units

into various strata. The method is quite efficient provided the sample is reasonably large, i.e. greater than 20 in every stratum and the effects of errors in the weights of strata can be ignored.

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Important New Ideas

STRATIFICATION	STRATIFIED SYSTEMATIC SAMPLING
PROPORTIONAL WEIGHTING	STRATIFIED QUASI-RANDOM SAMPLING
OPTIMUM ALLOCATION	STRATIFICATION CRITERIA
SUB-POPULATIONS	CONTROLLED SELECTION

5

CLUSTER, MULTI-PHASE AND REPLICATED SAMPLING TECHNIQUES

5.1 Cluster Sampling

CLUSTER sampling involves division of the population of elementary units under consideration into groups or clusters that serve as primary sampling units. A selection of the clusters is then made to make up the sample. Thus in cluster sampling, the sampling unit contains groups of elements (clusters) instead of individual members or items in the population. A *cluster* is an intact group as available in the field. It is not formed by the researcher for data collection.

For example, for the purpose of selecting a 10 per cent sample from all primary school children in New Delhi, the investigator may list up all the primary schools instead of all the primary school children, and select randomly a 10 per cent sample of the schools or clusters of units and include all the children in the selected schools in the sample. Although the unit of inquiry may be the individual child yet the unit of sampling is a school or cluster of children.

Let us consider another example. Suppose a survey of the households of a large town is to be conducted and the results about individual households are to be obtained. The unit of investigation is the individual household. Suppose further, that there are 30,000 households, all of them listed conveniently in the records of the local corporation and a sample of 300 households is to be selected. It can be done by picking up 300 households randomly from the list of households available in the corporation office. As a consequence of the use of the simple random method, the sample would be spread over the whole town which, in turn involves high field work costs and much inconvenience. But suppose, the town was divided into 600 blocks of 50 houses each, a simple course would be to

select at random six blocks, i.e. 1 per cent and include all the households in them in the sample.

In this way, the sample instead of being scattered over all the blocks will be confined to only six blocks. Suppose the information were to be collected by direct interviewing it would be more economical to contact the households because of the proximity of the same in six compact areas. In addition to this the advantage in the use of a cluster and not a household as sampling unit receives added importance in cases where an adequate listing of all the units of investigation in the population was not readily available. Listing of these units through direct contact would be highly expensive and time-consuming. Cluster sampling has been described in social surveys as "area sampling" and "area probability sampling". The latter term is somewhat misleading because simple random sampling can be used with areal units. Moreover, the area probability sampling is based to some extent on the principle that areal probability can be used for sampling purposes.

5.2 Some Other Cluster Sampling Designs

The examples given in the preceding pages illustrate the simplest method of drawing a cluster sample. There are many alternative ways of obtaining a cluster sample which involve more complex systems such as two-stage, three-stage and multi-stage sampling designs. The design may call for starting with larger units, just as provinces in a country; obtaining an initial sample of them; from the provinces so selected, choosing a specific number of districts; from the chosen districs, selecting a number of sub-division; and from the sub-divisions drawing a sample of farms, stores or households with equal probabilities of inclusion or with varying probabilities. It may also involve special procedures for sampling stores, hotels, farms, institutions and other special groups of the population.

5.3 Multi-phase Sampling

Multi-phase sampling involves collection of some information from the whole sample and additional information either at the same time or later from sub—samples of the full sample. After making a simple inexpensive survey of a large sample, an investigator may select sub-samples from it for a more comprehensive investigation.

For example, an investigator plans to conduct a household expenditure survey. The information to be collected is decided upon.

A sample of households is selected but each household is not questioned on all the matters being covered. Only the basic data-size and composition of the household, occupation of the head, income etc., are collected. Information regarding other important aspects such as distribution of expenditure over the main items may also be sought from the entire sample, because the analyses of results are to be based on this information. However, there may be some less important matters on which the investigator does not require detailed analyses of such high precision. Seeking less important type of information from the entire sample may impose a considerable burden on the respondents. The question then is : Can the burden be reduced ? The investigator then may select sub-samples from the main sample and question them on the less important issues and thus reduce the burden of answering on a very large section of the main sample. Moreover, information about certain factors known to be fairly constant in the population may be obtained by sub-samples without much loss in precision.

In addition to the consideration of lessening the burden of the respondents, the factors of high costs and difficulty in collecting some information may also warrant the use of only a small part of the entire sample for the purpose, thus involving the use of multi-phase sampling.

Multi-phase sampling may be distinguished from multi-stage sampling with which it can indeed be combined. The main distinction between the two lies in the use of unit of sampling at different levels. In the multi-stage sampling different types of sampling units (administrative districts, polling constituencies, individuals) are sampled at different sampling stages; in the multi-phase sampling, the investigator is concerned with the same type of sampling unit at each phase but some units are asked for more information than others. With only one sub-sample, the technique may be called two-phase sampling or double sampling.

The likely advantages of this procedure include reduction of burden on the respondents, considerable economies in terms of expenditure, time and labour and improvement of the precision of the sub-sample data through the information collected on the entire sample. Data collected during the first phase may be used for stratification purposes in the selection of the sub-sample.

Post-stratification ratio and regression estimation techniques can also be used to improve the precision of the sub-sample results. The effects of non-response in the sub-sample can be estimated,

unrepresentativeness of the remaining sample can be gauged on the basis of the basic data, and if necessary, re-weighting can be done to counteract the effects of unrepresentativeness.

However, it is important to know that the use of two-phase sampling for the sole purpose of increasing the precision of sub-sample results is effective only if the cost of data collection is considerably lower for members of the first phase sample than those of the sub-sample. Moser and Kalton[1] suggest that if two-phase sampling is to be useful, the gain in precision resulting from the use of first phase data to improve the sub-sample results must outweigh the loss in precision resulting from the reduction in sub-sample size. This is likely to occur only if the cost per individual of collecting the data at the first phase is cheaper than that at the second phase by a factor of at least, say ten. This degree of variation in costs can occur, for example, when the first phase information is taken from some form of records or collected by mailed questionnaires while the second phase information is obtained in personal interviews.

Two phase sampling may be useful in studying rare populations such as those of persons with rare diseases. The first phase may help in preliminary securing through an inexpensive method a large sample to detect the positive and negative cases and in the second phase the sub-sample for the purpose of more expensive and thorough examination.

Cartwright[2] in a study of "Human Relations and Hospital Care" used the technique of two-phase sampling to obtain a sample of persons who had been in hospital in a set period shortly before the survey was undertaken. The first phase sample consisted of 29,400 persons selected from the Register of Electors. Through a brief postal questionnaire, it was ascertained whether they had been in hospital during the period in which the investigator was interested. During the second phase, all the 1119 persons who had replied in the affirmative were interviewed. During the interview, 15 per cent of this sub-sample were found not to have been in hospital during the specific period, and hence their views about the hospital service were not sought. However, the views of the 100 per cent sub-sample taken from the positive stratum were recorded.

The Population Investigation Committee and the Scottish Council for Research in Education[3] conducted a survey of intelligence. A first phase sample of 80,000 children was used for group intelligence tests and for the main questionnaire. A more detailed questionnaire was then addressed to a sub-sample of children born on the first three days of each month. A further sub-sample comprising those born on the first day of

each alternative month was used for individual intelligence tests.

Multi-phase sampling is a popular technique in population censuses in various countries. In the 1961 Census in Britain, certain data - basic items like sex, age, marital condition and also items like number of living rooms, sinks, baths etc., were collected for the whole population and other data - e.g. occupation, place of work, age at which full time education ceased, qualifications in science or technology - were asked of only a 10 per cent sample.

5.4 Replicated Sampling

Deming[4] has discussed, in detail and with numerous illustrations, the technique of replicated or interpenetrating sampling. In the use of this technique a number of sub-samples rather than one sample are selected from the population. Each of the samples is based on a uniform sampling design, is self-contained, and adequate. For the purpose of selecting these sub-samples any basic sampling design with stratified or non-stratified, single or multi-stage, single or multi-phase approach can be used. The essential pre-conditions to be fulfilled include the independence of each sub-sample from the other, the uniformity of the sampling design and complete coverage of the population in each trial of selecting the sample.

For example, suppose a survey of level of Mathematical achievement of 8th class male students in the government and recognized schools in a district is to be conducted and a standardized test of Mathematics is to be administered to a sample of pre-determined size, say 1000 students. The full sample can be made up of two sub-samples of 500 each, or five sub-samples of 200 each, or ten sub-samples of 100 each, or whatever combination of number and size of sub-samples is required. These sub-samples have, however, to conform to the conditions mentioned above. Then the test can be administered to the sub-samples, the information scored and tabulated sub-sample wise. The sub-sample estimate can be used to find out the variation among them and thus an assessment of the precision of the overall estimate can be made. The sampling error is reflected in the variation between the sub-sample estimates.

If an overall sample is selected by using k independent sub-samples, Zi is the estimate for the ith sub-sample. The overall estimate will then be given by the mean of those estimates :

$$Z = {}^{1}/_{k}\, \Sigma\, Z_{i}$$

The standard error can be calculated by first calculating the standard deviation of the sub-sample estimates :

$$S_Z = \sqrt{\frac{1}{K-1}\Sigma\,(Z_i - \bar{Z})^2}$$

The standard error would then be :

$$SE(\bar{Z}) = \sqrt{\frac{S^2_z}{k}}$$

It may, however, be noted that these formulas are the same as used in the calculation of mean, standard deviation and standard error of the mean while using ungrouped raw scores and students of research who have done an elementary course in applied statistical techniques are expected to be conversant with them. The standard error formula given above is applicable to all forms of sampling procedures employed in drawing the sub-samples.

Merits and Limitations

One of the merits of replicated sampling technique is the ease of standard error calculation as compared to more complex designs e.g., multi-stage stratified sampling. Replicated sampling technique can be supported on two more counts. Sometimes when the total sample is too large to permit the survey results to be ready in time, one or more of the sub-samples or replications can be used to obtain advance results. It may be a practical consideration sometimes.

Another important merit concerns with the possibility of throwing light on variable non-sampling errors such as those due to interviewer variability in studies where interview was the major technique of data collection and more than one interviewer was used.

However, there are certain precautions to be observed in the use of the replicated sampling. *Firstly,* each of the sub-samples has to be a random sample of the whole, otherwise they cannot be considered as comparable and difference between them as an unbiased estimate of between-interviewer-variation cannot be taken. For example, it would not be good if for the purpose of taking two samples the whole population is divided according to sex and samples are taken one from each sex group. Division of the population on the basis of Arts group and Science group, rural and urban setting or some other criteria and selection of the

samples one each from the two groups will also confound the results. The difference between the results of the two sub-samples would not constitute a criterion of the difference between interviewers. It will then not be possible to know how much of the difference was due to special groups and how much to interviewers.

Secondly, since the numbers in the sub-samples tend to be small, detailed investigation of the interviewer errors is rarely possible, only the major sources of variation being discovered.

The systematic errors common to all interviewers and the compensating errors will not be disclosed. The former will appear equally in the separate sub-samples and the latter will cancel each other out over an interviewer's assignment. Hence replicated sampling, although a valuable means of investigating non-sampling errors, must not be treated as a substitute for careful field work, supervision and control.

Another important decision to be made while using replicated sampling pertains to the number of sub-samples or replications to be employed. Mahalanobis[5] used four replications in most of the studies reported by him. Deming[6] has very often used ten replications. The decision regarding the number of replications, however, rests on the purpose of the survey. If it is used as a means of studying non-sampling errors such as inter-interviewer differences, only a small number of replications, as used by Mahalanobis,[7] may be employed and each sub-sample allocated to each individual interviewer. On the other hand, if it is to be used to obtain simple estimates of standard errors, more replications are desirable to ensure greater precision for these estimates. This question has been discussed in greater detail in Moser and Kalton.[8]

Another limitation of the method is the severe restriction that it places on the amount of stratification that can be employed. Moser and Kalton[9] give the following illustration. Take, for instance, the case of a multi-phase sample with, say, sixty PSU (Primary Sampling Units) to be selected and ten replications. As each replication must contain at least one PSU from each stratum, there must be at least ten PSU's selected from each stratum. As a consequence, with the limitation of sixty PSU's in all, there can be no more than six strata. In the selection of PSU's it is usually advantageous to have more strata than this, and so this limitation is a real drawback to the use of replicated sampling with multi-stage sampling.

However, this limitation is often unimportant while using single stage sampling. *Firstly*, because there is often less stratification

information available. *Secondly*, in single stage sampling in the case of 1000 PSU's and ten replications, there can be as many as 100 strata which would nearly be more than sufficient for the purpose.

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Important New Ideas

CLUSTER
CLUSTER RANDOM SAMPLING
TWO STAGE SAMPLING
MULTI-PHASE SAMPLING
MULTI STAGE SAMPLING
PRIMARY SAMPLING UNITS (PSU)
REPLICATED SAMPLING
POST STRATIFICATION RATIO

6

NON-PROBABILITY SAMPLING METHODS

6.1 Introduction

SAMPLES which are selected through non-random methods are called non-probability samples. Depending on the technique used, these are sometimes called accidental, incidental, purposive, convenience and quota samples. Since the term non-random is the most expressive of their nature these may be designated as non-random samples. The main feature of these samples is the lack of control of the sampling error. Hence these can also be referred to as "uncontrolled" sampling methods. Since the selection of the units in these samples is based on judgement and not on equal or known probability, the same as a class, are known as non-probability sampling methods. In this chapter a description of the various non-probability methods of sampling is given. It is followed by a critical appraisal of the same.

6.2 Incidental Sampling

The term "incidental sampling" (also called accidental sampling) is generally applied to those groups which are used chiefly because they are easily or readily obtainable. A researcher employed in a school of psychology may use the students enrolled in that department; a professor of education may undertake a study using the students enrolled in education classes and a research worker may use the children of the local schools or animals available in the local laboratory. These subjects are available in number, and under conditions none of which may be of the experimenter's choosing. Such casual groups rarely constitute random samples of any definable population.

The main considerations in terms of merits of such a procedure are: the administrative convenience of obtaining subjects for the study, the ease of testing, saving in time and completeness of the data collected. The

demerits of such a procedure lie in the fact that since there is no well defined population and no random method of selecting the sample has been used, standard error formulas apply with a high degree of approximation if at all to incidental samples and no valid generalizations can be drawn. Any attempt at generalization based on such data will be misleading.

6.3 Purposive Sampling or Expert-Choice Sampling

Samples are sometimes expressly chosen because, in the light of available information, these mirror some larger group with reference to one or more given characteristics. The controls in such samples are usually identified as representative areas (city, county, state, district), representative characteristics of individuals (age, sex, marital status, socio-economic status, race) or types of groups (school administrators, school counsellors, elementary teachers, secondary school teachers, college teachers, editors of dailies, housewives, visitors to a religious shrine). These controls may be further subdivided by specified categories within classes such as amount of training, years of experience, or attitudes toward a specific phenomenon. Up to this stage, these controls are somewhat similar to those used in stratification. The researcher may select the number of cases in the sample proportionate to the total number of such cases with "control" characteristics in the population. It is also important to know whether these proportions were based on adequate information or scant and partial information about the population.

Some examples of purposive sampling in social science research are: newspaper editors reflecting accurately the public opinion upon various social and economic questions in their own region; a sample of housewives representing accurately the buyers of canned goods; and a sample of brokers reflecting the opinion of financiers on a new stock issue. If the saying "As Maine goes, so goes the Nation" is accepted as correct, then Maine becomes an important barometer (a purposive sample) of political thinking.

In another approach, experts choose "typical" or "representative" cases on the assumption that with judgement and reason a satisfactory sample can be chosen. For example, a teacher selects a few students as typical or representative of the student body as a whole; a principal selects a typical teacher to be interviewed by the press. Sometimes experts are used to select atypical cases.

Purposive sampling differs from stratified random sampling in that the actual selection of the units to be included in the sample in each group is done purposively rather than by random method. The former is not a satisfactory procedure if high precision is required. There is absolutely no reason to believe that important characteristics are representative of the population when two or three characteristics are representative. A considerable research evidence has been put forward against such a belief. From the statistical point of view also this technique is particularly weak. There is no way of calculating the limits of permissible error, or the required number for the sample, if strict probability sampling is not used.

The purposive sampling approach may be useful where it is necessary to include a very small number of units in the sample. Thus if one were faced with the problem of finding one district or even five or perhaps a dozen districts to represent the whole of a big country, purposive selection might be the best approach. A sample of one district or five districts cannot ordinarily be found to represent a big country on a number of characteristics unless the investigator was extremely fortunate, or unless the answer to the problem was known for all practical purposes before the samples were selected; or unless there is no variability between areas in the desired characteristics.

Hansen, Hurwitz and Madow define the use of purposive sampling in certain special situations in the following words :

> A method based on purposive selection is biased, but the biases probably would be smaller for a sample of one county selected to represent the United States, than the random errors would be in measurable method that depended on a random selection of a single county. On the other hand if the sample is to include a considerable number of units, then the biases of these purposive methods often will be more serious than the random errors introduced by the methods discussed in this book in which random or chance selection rather than purposive selection is used.[1]

6.4 Quota Sampling

Quota sampling is another non-probability sampling method. It involves the selection of the sample units within each stratum or quota, on the basis of the judgement of the interviewers rather than on calculable chance of being included in it.

" A wide variety of procedures go under the name of quota sampling,

but what distinguishes them all fundamentally from probability sampling is that, once the general breakdown of the sample is decided (e.g. how many men and women, how many people in each age group and in each 'social class' it is to include) and the quota assignments are allocated to interviewers, the choice of the actual sample units to fit into this framework is left to the interviewers. Quota sampling, is, therefore, a method of stratified sampling in which the selection within strata is non-random. It is this non-random element that constitutes its greatest weakness."[2]

For example, let us suppose that a national opinion survey based on quota sampling method is to be conducted. The first step will be to stratify by region, by rural/urban area and perhaps by administrative districts or constituencies within these broad strata. In this way, the quota sampling, in its initial stages, is similar to stratified random sampling. It may, although not necessarily, employ random selection procedures at the initial stages of selection in exactly the same way as probability sampling. The essential difference between probability and quota samples lies in the selection of the final sampling units, say, individuals.

In quota sampling each interviewer is assigned a specific number of interviews with specified categories of persons—men and women, age groups, social classes and the like. These quotas are determined according to the proportions of these groups in the population. The factors of stratification or quota assignments are called controls and their value lies in the fact that they separate the population into strata which differ in their opinions on the subject under study. If a control fails to do so it is of no value. Another consideration in the choice of these controls is that the resulting strata should, as far as possible, be homogeneous with respect to their members' availability for interview.

Age, sex and social class are the three universally used quota controls. While age and sex are easy to ascertain, it is very difficult to define social class. Firstly, there is no reliable statistical basis for setting the quotas because the definition of social class usually involves a combination of objective factors such as occupation and income, and subjective factors like appearance, speech and the like. Secondly, the definition is very often vague and thus leaves much freedom to the interviewer's subjective judgement and hence bias. These major controls may be supplemented by special controls such as housewife/not housewife, head/not head of the family, occupation and industry, marital

status. However, the use of many extra controls may make the interviewer's task difficult.

On the issue of quota sampling versus probability sampling, Moser and Kalton say "Some experts hold the quota method to be so unreliable and prone to bias to be almost worthless; others think that, although it is obviously less sound theoretically than probability sampling, it can be used safely on some subjects; still others believe that with adequate safeguards quota sampling can be made highly reliable and the extra cost of probability sampling is not worthwhile. In general, statisticians have criticized the method for its theoretical weakness, while market and opinion researchers have defended it for cheapness and administrative convenience."[3]

Rummel points out the weakness of the quota sampling method in the following words :

" In quota sampling an interviewer is given a quota of cases he is to select bearing each of several pre-determined characteristics similar to those involved in purposive sampling but he is given considerable freedom in choosing the individual cases. This may lead to large biases, since those who are often available at the times and places the interviewer meets them are not representative of the population. Often times interviewers have used the line of the least resistance in meeting their quotas and have collected information only from those who were easily available for interview and have ignored people in areas more difficult to reach. Poor supervision of interviewing teams and inadequately defined controls have led to results that have caused serious criticisms of the method."[4]

Another important and crucial issue in quota sampling is—does it end with representative samples of the population. Moser and Stuart[5], through a comparison of the occupation distribution achieved by two comparable surveys, one based on a national quota sampling and the other on a national random sample, illustrate as to how very large differences in the proportions may be introduced. The occupation distributions obtained through the two types of sampling methods are given on next page :

Table 6.1

Percentage Distribution by Occupation/Industry Quota and Random Samples

Occupation/Industry	Men		Women	
	Quota Sampling	Random Sampling	Quota Sampling	Random Sampling
Manufacturing	6.5	24.9	4.3	7.2
Clerical	3.8	5.0	4.2	4.6
Distributive	15.7	5.9	9.0	3.0
Transport and Public Service	18.3	7.6	1.3	—
Professional and Managerial	18.1	20.0	5.4	3.2
Mining and Quarry making	1.4	4.6	—	—
Building and Road Making	14.3	6.3	0.2	—
Agriculture	2.4	2.8	0.3	0.8
Other Industries	15.5	8.1	10.3	5.5
Housewives	—	2.0	64.8	69.2
Retired, unoccupied, Part time	4.0	12.6	0.2	6.6
Not Stated	—	0.2	—	—
Total	100.0	100.0	100.0	100.0

Source : Quota sample—British Market Research Bureau ; Random sample-Government Social Survey.

The table shows a large excess in the quota sample of persons employed in distribution, transport, the public services, and building and road making. A correspondingly small proportion of persons are

employed in manufacturing. The random sample proportions were found to be broadly correct in comparison with data obtained through other sources.

Before the discussion of the quota sampling method is concluded it would be appropriate to sum up the main points made so far. The quota method involves the use of strata, but selection within the strata, is not done on a random basis—the field worker merely fills a quota by securing the correct proportion per stratum. The chief *merits* of the quota sampling are : *firstly*, the method is less expensive. However, the greater the controls involved, the more expensive is the quota sample, but the smaller will be the risk of selection biases. While no accurate comparisons of the cost are possible, it is generally suggested that in quota sampling an interview costs, on the average, only a half or a third as much as a random interview. It is so because in the former, there are no call-backs and the field worker has not to travel all over the town to track down pre-selected respondents. *Secondly*, administrative convenience is another advantage of quota sampling. The labour of random sample selection and the headaches of non-contacts and call backs are avoided. Moser and Stuart[6] point out that—although there are no non-contacts in terms of pre-selected respondents, refusals in one study were found to be 8 percent. *Thirdly*, quota sampling is the only practicable method of sampling a population for which no suitable frame is available. In a market research study concerned to find out the characteristics of smokers of a particular brand of cigarette, the population comprises only a small proportion of the total population, is sparsely spread over the country and is not listed on its own and hence no suitable frame is available. Quota sampling is the only practicable way to sample such populations. *Lastly*, in studies where the field work has to be done quickly to reduce memory errors quota sampling is the only answer. In audience research surveys conducted by various broadcasting concerns, to obtain the public reaction to their programmes, sometimes to the previous day's programme-quota sampling is the only method to contact a national or provincial sample. Sudman[7,8] reports survey of immediate public reaction to President John F. Kennedy's assassination completed in about ten days, through quota sampling.

The main *criticism* of quota sampling is based on the following points. Firstly, that unlike random sampling it is not possible to attach estimates of standard errors to the quota sample results. The use of

replicated method for the purpose will be very costly and difficult to set up. Secondly, the method does not allow for an easy supervision of the field workers. Thus the correctness of the data collected remains doubtful. Lastly, although quota samples generally claim that instructions to, and constraints on field workers are sufficient to guard against the main dangers of selection bias, but it is a matter of belief rather than facts. Hence it remains doubtful whether quota sample was representative of the population.

Attempts have been made to make the quota sampling more scientific through a combination of random and quota methods. Some quota samplers issue exact instructions to the interviewers for following a standard procedure. They may be told to contact every third house and interview one person until their quota was filled. Sudman[9,10] applied detailed geographical controls and prescribed a specific travel pattern for the interviewers. The modified method is called "probability sampling with quotas."

6.5 Sequential Sampling

Sequential sampling is another sampling design of relatively recent origin. In this design, sampling is continued until a significant result on which to base a decision is obtained. Thus, instead of carrying out a study of four hundred cases, it might be advisable to carry out, for instance, a four-stage sequential research programme of one hundred cases each. As soon as a decisive answer is provided, the study is dropped, may it be at the end of the first or the second stage. In case conclusive results have not been obtained until the expiry of the first or second stage, the study is continued until the answer is obtained, or until the four hundred cases are exhausted. Mouly has illustrated this technique in the following words :

"For instance, a manufacturer having devised a new light bulb would want to test this bulb for life expectancy before placing it on the market. Since testing the bulb would imply its destruction, he would want to conduct the test as economically as possible. This he might do by testing, perhaps, fifty bulbs. If these, proved to be significantly superior or significantly inferior to the conventional bulbs, he would then have his answer. If, however, the test proved to be inconclusive, he would then have to add another fifty bulbs. This might provide a conclusive answer; if not, the test would be continued by the addition of one batch of fifty bulbs after another until the issue is settled one way or the other and at a minimum expense.[11]"

The design can incorporate random and non-random techniques depending on the requirements of a particular study. The four batches of fifty bulbs each can be chosen randomly from one lot of 10,000 bulbs produced. These batches could be the first 200 produced by the manufacturer and further production suspended until a conclusive answer to their superiority or inferiority to the conventional bulbs was obtained. Another strength of this procedure is that if a basic flaw is noted in the design of the study, the first stage could be considered a pilot study of the others which would then be conducted on the basis of the improved design. Considerable economies in terms of time, labour and expenditure can be made more so, in case of research on very precious articles of production.

6.6 Snowball Sampling

The term "snowball sampling" has been used to describe a sampling procedure in which the sample goes on becoming bigger and bigger as the observation or study proceeds. For example, an opinion survey is to be conducted on smokers of a particular brand of cigarette. At the first stage, we may pick up a few persons who are known to us or can be identified to be the smokers of that brand. At the time of interviewing them, we may obtain the names of other persons known to the first stage subjects. Thus the subjects go on serving as informants for the identification of more subjects and the sample goes on increasing. *The term snowball stems from the analogy of a snowball, which begins small but becomes bigger and bigger as it rolls downhill.*

Tenhouten et al[12] have developed a strategy for drawing a probabilistic snowball sample which would allow computation of estimates of sampling error and use of statistical tests of significance. Snowball sampling which is generally considered to be nonprobabilistic can be converted into probabilistic by selecting subjects randomly within each stage. For a nonprobabilistic sample, some method such as quota sampling can be used at each stage.

6.7 Dimensional Sampling

It is a variant of quota sampling and can be viewed basically as a multidimensional form of quota sampling. All dimensions or variables of interest to the researcher in the population, are specified and it is ensured that every combination of these dimensions is represented by at least one case. The procedure is as follows :[13]

1. Explicitly delineate the universe to which you eventually wish to generalize;
2. Spell out what appear to be the most important dimensions along which the members of this universe vary and develop a typology that includes the various combinations of values on these dimensions; and
3. Use this typology as a sampling frame for selecting a small number of cases from the universe, typically drawing one case from each cell of the typology.

The basic purpose is to eliminate the possibility of non-representation of any combination in the sample. The hypothetical example given below may serve the purpose of further clarification. Suppose, a survey of the opinion about the functioning of the present congress (I) government in India is to be conducted. The degree of commitment to Congress ideology and whether this commitment is intact or not are two important dimensions or variables of interest to the researcher. The typology can be diagramed as below :

Whether intact or Not	Degree of Commitment to: Strong	Moderate
Intact	Congress (I) Leaders	Leaders of other parties
Not intact	Former Congress Leaders	Former Leaders of other parties

Fig. 6.1 Typology in Dimensional Sampling

Dimensional sampling ensures that each of these four cells is represented even in a very small sample.

6.8 General Evaluation

An interesting experiment described by Yates illustrates the inadequacy of the judgement selection in a rather striking fashion. The experiment pertains to the selection by each of the 12 judges of three samples each of 20 stones from a collection of about 1200 stones spread out on a table. The judges were asked to select their samples in such a manner that each sample represented as nearly as possible the size distribution of the whole

collection. The results showed the following types of divergences from representativeness of the samples from the population.

1. Consistently nearly all observers over-estimated the average size of the whole collection.
2. Only 6 of the 36 estimates were smaller than the true average weight and 3 of these were made by a single judge.
3. The judges selected stones as near their concept of average size as possible.
4. The proportion of the extreme size selected was much smaller than would be obtained in a random selection.

To sum up, the experiment demonstrated that in judgment sampling there was a consistent tendency on the part of the judges to over-estimate the average size and under-estimate the variances.

No statistical theory has been devised to measure the reliability of sample results by purposive and other non-random sampling methods. In some instances, however, it may be practically impossible to use probability sampling such as in drawing a sample of fish from the sea, or a sample of a specific type of wild life from the forest. Sometimes although the sample may be designated as probability sample, yet the incompleteness of the responses due to refusal and non co-operation of the respondents even after several attempts at persuasion, may take away the quality of randomness from the sample and measurement of reliability of the estimates may become impossible. The problem of non-response has been discussed in detail in the chapter to follow.

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Important New Ideas

INCIDENTAL SAMPLING
ACCIDENTAL SAMPLING
UNCONTROLLED SAMPLING
CONVENIENCE SAMPLING
PURPOSIVE SAMPLING
EXPERT - CHOICE SAMPLING
QUOTA SAMPLING
TYPICAL CASES
SEQUENTIAL SAMPLING
SNOW BALL SAMPLING
DIMENSIONAL SAMPLING
TYPOLOGY

7

SOME OTHER PROBLEMS

7.1 Longitudinal Studies

In longitudinal studies, the aim is to collect data from the same sample on more than one occasion. The first step is to obtain a sample through any of the probability sampling techniques. The second step and the more arduous one is the maintenance of the sample representativeness. The information is then sought from this sample at intervals. The sample thus used is called panel and hence in some books on research this method is referred to as "panel studies".

The technique is specially useful in experimental and pre-experimental designs[1]. In such studies, the effects of specifically introduced measures such as advertisement, a speech and the like are explored. The "before-after design" without control group as explained by Campbell and Stanley[2] has several inherent weaknesses of internal validity. However, the true experimental designs such as "pre-test post-test single control group design" and the one with several control groups are to be preferred in such cases. In these designs, the investigator starts with more than one panel of which some are tested only once (pre-test only or post-test only) and others twice (pre-test and post-test).

The panel studies are further useful in "time series design[3]." It involves taking of several observations on the predicand (say O_1, O_2, O_3, O_4) at intervals prior to the introduction of the predictor variable and then several observations (O_5 O_6, O_7, and O_8) afterwards. If no change occurred in the first four or the last four observations, or if there was a steady trend in each group of four and if there was discontinuity between O_4 and O_5, the conclusion that the predictor caused the change in the predicand could be made more safely than if there were only one before and one after-measurement as in the before-after design described in the preceding paragraph. The main strength of the design lies in its extra measurements which make it less likely that maturation and testing are sources of

invalidity. However, the discontinuity in O_4 and O_5 cannot be easily accounted for as "history" still remains a major source of invalidity because of the possibility that some event other than the predictor, occurring between O_4 and O_5 caused the discontinuity. Another advantage of taking multiple observations is to detect the transient effect because in a study predictor's effect might decay with time or it has its maximum impact some time after its administration.

Another advantage of the panel study is greater precision. It nearly always measures changes with greater precision than does a series of independent samples of the same size. The variance of the change is lower for a panel study than for completely independent samples. The techniques of matching and blocking in experiments also serve this purpose to some extent by introducing positive correlation between matched pairs or groups.

Moser and Kalton point out another advantage of panel studies in the following words :

They enable the researcher to measure not only net changes (which independent samples could do also) but in addition to identify and study the 'changers'. The data can be conveniently set out in a turnover table——[4]."

These authors have given a turnover table which contains two examples.

Table 7.1

Examples of a Turnover Table

Example 1

Period 1	Favour x	Period 2 Do not Favour x	Percent Total
Favour x	48	0	48
Do not Favour x	6	46	52
Total	54	46	100

Example 2

Period 1	Favour x	Period 2 Do not Favour x	Percent Total
Favour x	20	28	48
Donot Favour x	34	18	52
Total	54	46	100

In both examples, 48 per cent favoured brand X in period 1 and 54 per cent favoured it in period 2, but there is nevertheless a marked difference between the two sets of data. In Example 1, there are very few changes, with no one ceasing to favour Brand X and just 6 per cent changing to favour Brand X in period 2. In Example 2, on the other hand, although the net change is the same 6 per cent increase in those favouring Brand X-there is a great deal of change with 62 per cent of the respondents changing their answer between the two periods. By means of the turnover table, the panel method makes it possible to measure gross as well as net changes.

Relationships between questions asked at the same time be investigated from a single survey, but the relationship on an individual basis between the answer to questions asked at different times, often of great interest in social research, can only be investigated through panel study.

Another important factor in causal analysis is the temporal ordering of variables. A cross sectional study may find a relationship between two variables such as worker's attitude towards his job and his position in the firm, but it cannot indicate which came first. A panel study recording promotions and measuring workers' attitude at intervals would provide data for distinguishing between these two possible explanations of the relationship.

There are certain administrative advantages of the panels also. The costs of sample selection is reduced and planning of field work can be effective and easy. In the case of full co-operation from the respondents, fuller and more reliable data can be obtained.

The main problems in panel studies are :

(i) Achievement of the initial sample,
(ii) Sample mortality and
(iii) Sample conditioning.

The recruitment of a representative panel of respondents to provide detailed information regularly at set intervals is a difficult task. A housewife may agree to answer a few questions on one occasion but may refuse to provide detailed information about her monthly purchases, use of various vegetables in kitchen, a list of entertainments the family enjoyed in a month, the category of guests she had to entertain at her house, and the like for extended periods of, say, a year or two.

The problem of mortality in such studies arises in more than one ways. It is the experience of many researchers that the first few reporting periods (weeks, months, or quarters) always take a heavy toll of panel membership. The rate of mortality decreases afterwards and the membership settles down.

Wordsworth,[5] Le Measurier[6] and Ehrenberg[7] have described Attwood Consumer Panel which was required to record purchases covering a wide range of non-durable goods in a weekly diary. Initially 80 per cent of the contact agreed to be enrolled on the panel but by the time of the "first" reporting period 16 per cent of these failed to co-operate thus leaving only 64 per cent of the sample. The Attwood panel lost a further 16 per cent of the total and thus 48 per cent of the original membership settled finally. Although the drop-outs were replaced by households with similar demographic characteristics yet it was difficult to ascertain as to how typical those who dropped out or refused to cooperate were of the remainder. The drop-outs might have been less literate, busier, had bigger families and less interested in the sample and so on. Sobol[8] has reported the panel mortality and panel bias in a five-way study of economic attitude formation and change, plans to buy cars and durable goods, in fulfilment of these plans. The study was conducted by the Survey Research Centre, University of Michigan. The respondents who drop out during the life of the panel can be compared with those remaining in terms of their earlier responses. The composition of the remaining sample can be checked against known data on some factors. But it may provide, at the most a partial reassurance. Its representativeness with regard to the behaviour and attitudes that are the subject of survey must remain in doubt. In panel studies, the greater the burden on respondents, the bigger, the problem of drop-out and refusals.

The second source of the panel mortality is the difficulty of tracing the respondents, especially when the interval between the interviews is as long as a year or more. Some of them will move house and it may be difficult to trace them to their new address. However, methods like checking with the post office for their forwarding addresses, consulting telephone directories and contacting their closest relative whose address had already been obtained may help in tracing the respondents.

Depletion of the panel through deaths and emigration is another hazard. But these losses represent natural decrease in the population and do not cause a bias in the panel. The panel survivors are a representative sample of the surviving population. However, a supplementary sample of the new births (or people reaching the age set for the defined population) and new immigrants is required to make the panel representative of the full current population.

Repeated interviews with the panel members may lead to "panel conditioning", thus making it untypical, in characteristics although not in composition, of the population it was selected to represent. Members of a radio listening panel may gradually become more critical of programmes, more interested and more attentive. Conditioning may also change the accuracy of reporting. Through experience improvement in memory may take place and thus lead to a more accurate recall of events. However, in cases where detailed records are required, completeness of the recording may decrease over time through fatigue.

7.2 Master Samples

Some studies require repeated samples of the same area or population. In such cases, a master sample may be prepared from which sub-samples can be taken as and when required. The main advantages of this procedure are : simplicity of selection procedures and greater speed in obtaining a sample as and when required.

King and Jessen[9,10] have described the US Master Sample of Agriculture for which the county was divided into a large number of small areas and a master sample of 70,000, representative of every county, was constructed. Sub-samples from this could be drawn to give whatever regional or national coverage was required for a survey.

However, it is important that the sample units into which a master sample is divided should be relatively permanent. A master sample of individuals or households will quickly become out-dated due to deaths, births and removals. A master sample of dwellings will be relatively more

permanent and hence of more long-term usefulness.

7.3 The Problems of Non-response

The term no -response may be defined to refer to the failure to measure some of the units in the selected sample. Non-response is a problem no investigator of human populations can escape. He can never get information about more than a part of the survey material. This is true of complete coverage studies as well as of sample surveys. Non-response does not include the units that fall outside the population. The sampling frame may include units that field investigation reveals to be non-existent such as demolished houses, non-existent addresses and the dead. These units are considered to be blanks on the sampling frame and not as non-response. It is, therefore, advisable to subtract the number of blanks from the sample size before calculating the non-response rate. These blanks may be filled by substituting randomly selected units in order to keep the sample up to the required size.

(i) Sources of Non-response

Non-response occurs through various sources. Some of the more important of these are given below :

(a) *Unable to answer* : The respondents may not have the information sought for or may refuse to answer due to some extraneous fears. The sample is likely to include some people too infirm, deaf or unfamiliar with the language to be interviewable. If a respondent puts the interviewer off with an excuse of illness or lack of time, here is a case for calling back at another time and not for leaving him as "Uninterviewable".

(b) *The Unaccessible* : This category consists of those units in the sample which could not be located or visited due to certain reasons such as use of incomplete lists, bad weather and poor transportation facilities.

(c) *Not-at-homes* : This group contains two types of persons and households-those who remain away from home for longer than the field work period, so that ordinary re-calling is inapplicable and those who reside at home but are temporarily away from the house when the interviewer calls and can be contacted by re-calling. Persons who find it inconvenient at one time and on whom a callback can be made are also included in this category.

(d) *Refusals* : Surveys like population census carry compulsory powers and a refusal to answer is punishable. In other surveys, invariably some people do adamantly refuse to answer for one reason or the other.

This section of non-respondents can be designated as the "hard core". It represents a source of bias in the results because of the incompleteness of the returns.

All the sources of non-response mentioned above apply to random sample surveys in which the units are pre-selected and to be interviewed at home. Where interviewing is to be done in factories, schools, colleges, offices and so forth, or a main questionnaire is to be used, some of the above categories do not apply. In quota sampling, failures to interview are not recorded since the interviewer simply goes on to the next house or unit.

The magnitude of the problem of non-response due to various sources is likely to differ from survey to survey. It further depends on the study, the number of questions to be answered and the category of persons to be covered. A survey of personal incomes or saving is likely to generate larger non-response than a survey of food habits. In straightforward interview surveys where answering a few questions is required, the non-response will be lower than in those which require keeping of lengthy and detailed accounts. In surveys of the latter type a response rate of 70 per cent is considered quite good while in the former, a typical rate is probably nearer to 80 per cent. Moser and Kalton say,

"We may assume that, in the average interview survey, there will be no information through non-response from something like 10 to 25 per cent of the selected sample, and there is much evidence in the survey literature that non-respondents and respondents differ in important respects. Housewives with large families are more likely to be found at home than those with few or no children ; day time interviewing will fail to find many young people and working men at home : keen cinema goers and greyhound enthusiasts are less likely to be found at home in the evenings than others. Nor is willingness to cooperate likely to spread evenly over the whole population."[11]

Several attempts have been made to find out the differences in response rates due to sex, age social class and other variables. Moser and Stuart[12] report the following refusal rates in a quota sampling survey.

Table 7.2

Refusal Rates in an Experimental Survey-by Sex, Age and Social Class (Percentages)

Sex		Age Group		Social Class	
Male	6.1	20-29	4.6	Upper	12.2
Female	8.9	30-44	6.1	Middle	9.7
		45-64	11.0	Lower	6.3
		65 +	7.5		

Differences in the refusal rates between male and female, age group 45-64 and each of the other three, and upper and lower social classes are striking.

(ii) How to Deal with the Problem ?

Several approaches to the problem of non-response have been suggested in the literature on survey research. Some of the more important of these are described below :

1. *Substitution*

The non-respondents can be replaced by respondents and the sample kept up to the desired size. It would ensure adequacy of numbers for the intended analysis and keep sampling errors to their estimated magnitude. It is useful also in situations where the strata are not represented in the achieved sample in the planned proportions. In such situations, as far as possible, the substitutes should be taken at random from a reserve list drawn together with the initial sample. However, the risk of bias is not altogether eliminated. The danger arises from the possibility that non-respondents differ significantly from respondents.

2. *Increasing the Response Rate*

(a) Response rate for different types of non-response can be increased through a skilful handling of the situation. A particularly good interviewer may manage to obtain response from the partially deaf, the partially unable-to-speak a particular language, and the less determined to answer.

(b) Some of the "movers" can be tracked down by obtaining their forwarding addresses from the postal authorities or their neighbours. Another approach to deal with the problem is to substitute for the moved household, the new one that has moved in. Kish[13] used, a selection table

to define a rigorous procedure for selecting an individual from the new household. It reduces the bias due to substitution to a negligible minimum and the movers can be correctly represented in the final sample. One of the flaws of the Kish Selection Table is that it does not cover movers into new houses. For further details, see Kish[14] and Moser and Kalton[15].

(c) Gray, Corlett and Frankland[16] have suggested a re-weighting procedure for dealing with movers listed on the Register of Electors. The procedure is based on the assumption that the movers-in are representative of the movers-out and through the double weighting the former are included in the sample on their own account and also on behalf of the movers-out.

(d) It is a fact that the refusal rate depends a good deal on the researcher's and the interviewer's skill. Use of professional interviewers can cut down the rate of non-response. Durbin and Stuart[17], in an experiment on the relative efficacy of experienced and inexperienced interviewers, found that the experienced professional interviewers had 3 to 4 per cent refusals against the inexperienced amateurs' 13 per cent. A slight wisdom on the part of the surveyor can go a long way in minimizing refusals.

(i) The questionnaire should be kept as brief as possible so that the burden on the respondents is at a minimum.

(ii) Inducement of financial rewards will bring in more responses than no rewards.

(iii) The sponsorship should be strong and acceptable to the respondents.

(iv) The importance of the survey should be clearly impressed upon the respondents and their personal involvement, if any, be brought home to them.

(v) The time of making calls should be wisely fixed. Where the sex of the respondents is known before hand, call on the male respondents should be made in the evenings while female respondents with large families can be contacted during the day. Call-backs can be arranged through appointments at the time of the first call, or by ascertaining the time at which the respondent was likely to be available. Durbin and Stuart[18] report that when an appointment had been made 71 per cent of the second calls resulted in interview as against 40 per cent when no appointment had been made.

3. Appointments on Telephone

The use of telephone for making prior appointment has been made

and the success of the method demonstrated. Sudman[19] showed that through making telephone appointment the average number of calls required to complete an interview was 1.7 compared with 2.3 calls per completed case with no telephone appointment. Scott and Jackson[20] also demonstrated that by making telephone appointments for an interview survey, the number of personal calls can be reduced without an appreciable increase in non-response. In a country like India where only a small section of the population owns telephones, the system is not practicable.

However, appointments made in person or on telephone, may prove a double-edged weapon in that some people may make doubly sure of being out or not answering the door bell when the interviewer calls. Brunner and Carroll[21] report a marked detrimental effect of appointments on response rate.

4. Call-backs

However sensibly timed and arranged the first calls are, a surveyor would be extremely fortunate if he gets a 100 per cent response rate at them. Hence successive calls become necessary for completing the survey and reducing the bias due to non-response. A standard technique is to specify the number of call-backs, or a minimum number, that must be made on any unit before it is abandoned as "unable to contact". Stephen and McCarthy[22], on the basis of analysis of the results of a number of surveys, report the following information about the number of calls required for completed surveys :

Table 7.3

Number of Calls Required for Completed Interviews (Per Cent Sample Contacted on Successive Calls)

Respondents	First Call	Second Call	Third or later Call	Per Cent Non-response	TOTAL
Any Adult*	70	17	8	5	100
Random Adult	37	32	23	8	100

* "Any Adult" group included a housewife and a farm operator respectively in two different surveys.

Source : Average results as reported by Cochran.[23]

It is amply evident from the above table that the problem of completing the interview survey is easier when any adult in the home is capable of answering the question than in those in which a single adult, chosen at random, is to be interviewed. The marked success of the second call reflects the work of the interviewer in finding out in advance when the desired respondents would be at home and available.

On the use of call-backs two important considerations should not be lost sight of. Later calls would be expected to be more expensive per completed interview, since the houses are sparsely located in the area assigned to the interviewer. Durbin and Stuart[24] report the following figures in this regard :

Table 7.4

Relative Cost per New Completed Interview at the ith Call

Call	1	2	3	4	5
Relative Cost*	100	112	127	151	250

* Money spent on ith calls divided by number of new interviews obtained.

Another problem that arises out of call-backs is the time-factor. Call-backs delay the final results.

5. *Sampling in time for Non-respondents*

Another method of dealing with the problem of the not-at-home non-respondents was suggested by Hartley[25] and developed further by Politz and Simmons.[26] The method provides for sampling persons at random intervals of time, and inquiring of each one found at home as to other times he would have been at home during a specific period of time. For those persons actually found at home, the probability of being found at home during the specified time period is inferred from the response to the question on other times he was at home. If a random sample of points in time period is achieved, and if the response to the question on other times at home is accurate, the probability of a person being included in the sample can be determined. Then the value of a characteristic determined for each person in the sample can be weighted by the reciprocal of his probability of being included in the sample.

The method will yield consistent estimates if the sampling in time is

in fact at random and if the probability of being at home can be approximated satisfactorily. In practice serious problems may be involved in the effort to accomplish this.[27]

6. Comparisons

A random sub-sample of the non-respondents can be taken and a major effort to interview every one in the sub-sample can be made. Comparisons of respondents and non-respondents on sex ratio, age-distribution, social class grouping and various other characteristics can be made to find out if the non-respondents were broadly similar to the respondents. While this procedure may give the surveyor some confidence on the broad similarities of the two groups, it can never prove the absence of bias because it does not mean that the two groups are similar in respect of whatever it is the survey is studying.

Certain procedures have been suggested for adjusting for non-response bias. The adjustment is generally made by reweighting the results according to the correct proportions of different strata in the population. However, what must be clearly understood is the fact that reweighting ensures only that the sexes of different groups are correctly represented in the sample, it does not reduce any bias arising from unrepresentativeness within the strata, that is within each group.

To sum up, the aim of a sample is to estimate certain population characteristics as accurately as possible and it would be irrationally incorrect to leave a bad sample as it is. The methods and procedures described in this section can help in reducing the magnitude of the problem of non-response and thus raising the accuracy and validity of the results. Sometimes, it may well pay to keep the size of the sample smaller than what the sampling theory prescribes and spend the resources thus freed on securing a high response rate.

7.4 Sampling Techniques Used in Observation

Generally sampling involves persons, objects etc. However, in observation studies, sampling techniques may be used for taking out a sample of 'Time' out of a universe of 'Times'; a sample of 'events', out of a universe of 'events'; and a sample of 'situations' out of a universe of 'situations'. These methods are not so widely in use in surveys but form an important part of the observational techniques. Hence a brief description of these techniques is given below :

1. Time Sampling

The time-sampling technique requires that one record the frequency

of observable forms of occurrences during a number of definite time intervals that are systematically spaced.[27] The examples of time sampling are :

(i) Staff members may note the ongoing behaviour of a hospitalized psychiatric patient every 30 minutes.

(ii) We might instruct the parents of a child with behaviour problems to set aside one hour a day to observe and record their own and their child's behaviour.

(iii) We might also measure the blood pressure of a patient with essential hypertension every five minutes while exposing him to stressful stimuli.

(iv) Observers might go into the home of a married couple three times a week at suppertime to observe husband - wife interactions.

(v) A teacher or outside observer might record the behaviour of a first-grade child for five minutes during recess and lunch to help assess his social interaction behaviour.[28]

The student will find that in all these examples the observation occurs intermittently, at predetermined times and for predetermined duration. This is the simplest form of time sampling. Typically a target subject or group of subjects is identified; a block of time during which observations are to be made is specified and that block of time is further subdivided into smaller sampling intervals for the purpose of recording. Several variations of sampling time has been used by researchers. Only occurrence or non-occurrence of behaviours may be noted at random or specified times. When block of time are used, the term "interval time sampling" is used. In cases, where observation is done at random for small periods, the term "momemtary time sampling" is used.[29]

In some studies, alternate periods for observing and recording are used. A wide range of sampling times, durations and schedules have also been used by investigators in applied behavioural analysis. Parameters of sampling period include behaviour rate; behaviour variability over observation sessions; and situational specificity or variability of environmental stimuli controlling the occurrence of the behaviour.

Behaviour rates across observation sessions may be plotted to discern the trend. The graph may indicate a positive or negative slope. Slopes can be detected statistically, through visual inspection, or through slope or trend analysis.

2. *Event Sampling*

In event sampling, only selected behaviours in the subject's respective or selected environmental events are observed. The behaviour analyst selects one or a few events from the multitude of potentially observable target events. Behaviours are selected for observation as a function of several considerations such as :[30]

1. Nature of the referral problems,
2. Hypothesized controlling events,
3. Desired alternatives to a targeted problem,
4. The desirability of assessing side-effects, and
5. The desirability of assessing high rate behaviours which may covary with targeted low-rate behaviours.

Referred problems may include cases like the following :

A mother is concerned with a child's tantrums; a teacher is worried about a student's aggressive behaviour; and a college student may feel concerned about his attacks of anxiety.

Specification of referral questions help in determining whether observation is possible or some other method would be required. The suitability of participant and non-participant observation will also be assessed on the basis of this information. *The process of event sampling includes defining of a universe of targeted events and then to observe a sample of them.*

3. *Situation Sampling*

Behaviour is considered to be situation specific. Since the probability of behaviour frequently varies under different antecedent environmental situations, we should selectively observe a subject in situations where the probability of target behaviours is high.

Situation sampling is probably most frequently used in monitoring social behaviours such as family interactions, aggression, social interactions between children, and communication between marital partners. In these cases, we are interested in monitoring specific type of social interactions and, therefore, select situations in which these interactions are most likely to occur. These situations may be recess periods, lunch time, working on academic assignments, watching television, drug ingestion. Anti-social behaviours, lying, stealing and some psychotic disorders sometimes do not lend themselves readily to situation sampling. However, high rate behaviours like asthmatic

attacks, depressive talk, migraine headaches, hallucinations, aggression, social withdrawal etc., are easier to sample.

The three types of sampling discussed above lead to a loss in generalizability of the data. Applicability of inferences from time to time, event to event and situation to situation remains impossible.

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Important New Ideas

LONGITUDINAL STUDIES
PANEL STUDIES
SAMPLE MORTALITY
SAMPLE CONDITIONING
MASTER SAMPLES
NON-RESPONSE
REWEIGHTING OF SAMPLE
SUBSTITUTION
CALL-BACKS
TIME SAMPLING
EVENT SAMPLING
SITUATION SAMPLING
BEFORE-AFTER-DESIGN
PANEL MORTALITY
MOVERS
SAMPLING-IN-TIME

APPENDIX I

SUGGESTED FURTHER READINGS

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APPENDIX II

HOW TO USE RANDOM NUMBERS

THE SAMPLING theory often assumes that the sample at hand was drawn at random. Researchers very often try to accomplish this target. Yet actual accomplishment of randomness is extremely difficult by ordinary methods. The tables of random numbers, however, have been prepared by statisticians to facilitate the process of random selection. These tables have been so prepared as to allow an equal probability of selection to the numerals, 0-9.

The pre-requisite of the use of these tables is that it is practicable to count the observations and allot each a serial number. These observations may be anything such as observations located in a numbered file or in a book with numbered pages and lines or lists of names of schools or students, houses, streets, workers in a factory, shops in a town, trees on a tract of land and the like. A series of random numbers is selected from the table equal to the number of observations desired. The observations with the corresponding numbers are used. The columns of digits may be combined to give rise to numbers containing the requisite number of digits.

For example, it is desired to draw a sample of 200 cards containing specific information from numbered file containing 5675 cards. Since the card numbers involve a maximum of four digits, groups of four numbers may be used. Each of the tables given in the pages to follow has 40 columns and 25 rows. The tables can be used vertically or horizontally or diagonally.

The starting point can be at the beginning of the table or any other point located by throwing a pointed pencil on the table and picking up the digit close to the dot thus made by the tip of the pencil. In the example cited above, suppose it is decided to use the tables vertically, the first four columns are to be used. From the first thousand numbers, the first number selected is 2,315 (row 1, Column 1-4). The card with this number is

withdrawn from the file. The operation continues until the desired 200 cards have been obtained. After finishing the first four columns, numbers from the next four (5-8) columns be selected. If a number exceeds the largest number in the series i.e., 5675 in our example, it can be ignored or the largest multiple of n, (in this case 200) that can be subtracted from it, may be deducted from it and the remainder is the desired number card selected.

The steps in the use of tables of random numbers can be enumerated as below.

1. Give a serial number 1-N or 0-(N-1) to units of the population. In case of populations containing 100, 1000, or 10,000 or 10,00,000 cases, the following plan of numbering is more convenient and takes less time and labour in picking up the required number of cases from the table.

Population Size		Scheme of Serial Numbers	
100	=	00—99	(All numbers have two digits; use two columns)
1000	=	000—999	(All numbers have three digits; use three columns)
10000	=	0000—9999	(All numbers have four digits; use four columns)
100000	=	00000—99999	(All numbers have five digits; use five columns)

Thus in the selected columns there will be no number which will be larger than the largest in the series. The number of columns thus required will be less by one than what is required in the scheme using serial numbers 1—100, or 1—1000 etc.

2. Select a starting point as explained above.
3. Select the number of columns equal to the number of digits in the largest number of the series.
4. Go on selecting the numbers in a uniform way, vertically or horizontally or diagonally.
5. After finishing one column go to the next adjacent column.
6. If a number appears again, it may be ignored.
7. For different samples, start from a different point.

Kendall and Smith warn that "it was shown.... that the use of the same set of random numbers over and over in the same sampling experiment was illegitimate...."[1]. For this reason repeated samplings of the same population requiring more than the total numbers given in this book, should be accomplished by using more extended table such as may be found in Kendall and Smith[2], and Tippet[3].

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APPENDIX III

A RATING SCALE FOR SELF EVALUATION OF SAMPLING PROCEDURES APPLIED IN A RESEARCH STUDY

Section A

PLEASE answer each question on the basis of your own study. In case you do not remember everything you may consult your research report or other related records. Since it is a self-evaluation scale for your personal consumption and improvement if required, honesty and precision in answers will be self-rewarding. (Please use a tick mark for answering).

1. Have you defined the population or universe of your study ? Yes___ No___
2. Have you fixed up the limits of the population in terms of geographical, demographic and other relevant criteria? Yes___ No___
3. Can you say with full confidence that a particular unit or element belongs to your population ? Yes___ No___
4. Have you an assured access to all elements of the population ? Yes___ No___
5. Is the sampling frame available or can it be constructed easily? Yes___ No___
6. Have you checked and ensured that the sampling frame is uptodate and correct and does not have any omissions or duplications ? Yes___ No___

7. Have you made sure that the sampling frame does not exhibit any periodicity or other arrangements of elements ? Yes___ No___
8. Have you given a serial order to the elements or listed them up? Yes___ No___
9. Does the sampling frame contain elements according to the sampling unit such as individuals or groups or blocks etc.? Yes___ No___
10. Have you decided upon the sampling unit ? Yes___ No___
11. Does your sampling unit coincide with the experimental unit or unit of data collection and analysis ? Yes___ No___
12. Have you decided upon the size of the sample you wish to have? Yes___ No___
13. No personal judgment or intention has any place in the decision about the sample size ? Yes___ No___
14. Is the decision of sample size based on some sound statistical considerations ? Yes___ No___
15. Does the decision about sample size take care of the homogeneity or heterogeneity of the population ? Yes___ No___
16. Have you decided upon the magnitude of the error or discrepancy acceptable to you in deciding about the size of the sample ? Yes___ No___
17. Is your sample large enough to be adequate for the purpose of the study ? Yes___ No___
18. Is your sample size large enough to be representative of the population ? Yes___ No___
19. Are you using a probability sampling design ? Yes___ No___

20. Have you specifically mentioned the randomization technique used in your study ? Yes___ No___
21. Have you used tables of random numbers or some good mechanical device or computer services for the selection of the sample out of the serially arranged sampling frame ? Yes___ No___
22. Did you stratify the population and obtain/prepare sampling frames for sub-populations ? Yes___ No___
23. Were the criteria of stratification based on a sound evidence of their known relationship with the variables of the study ? Yes___ No___
24. Did you check whether the stratification criteria had no known relationship between/among themselves ? If yes, did you drop some of them ? Yes___ No___
25. Are you giving proportional/optimal representation to all stratification criteria ? Yes___ No___

METHOD OF SELF SCORING

Section A

Allot a credit of 1 to each 'Yes' ticked, and a credit of 0 to each 'No' ticked. Add up the scores. The maximum score can be 25 and the minimum possible score is 0. Now compare your score with the following to obtain a qualitative description.

Sampling

Very good	Good	Average	Poor	Very Poor
21 and above	16-20	11-15	6-10	1-5

Section B
Reporting Stage

How adequate and clear is your reporting ? Have you in your research report mentioned the following clearly and precisely ? Use a tick mark based on your own assessment of your reporting.

		Very clearly	Somewhat clearly	Not at all
1.	Population and its characteristics.	-	-	-
2.	Sampling frame and its sources.	-	-	-
3.	Sampling Unit.	-	-	-
4.	Precise Method or design of sampling such as simple random, cluster random etc.	-	-	-
5.	Fraction of the population taken as sample.	-	-	-
6.	Size of the sample.	-	-	-
7.	Composition of the sample in terms of sex, age group, other relevant variables.	-	-	-
8.	Sampling unit. (In two-stage or multi-stage sampling, unit at all stages)	-	-	-
9.	Number of persons or units from whom data actually collected.	-	-	-
10.	Number of cases of incomplete information (drop-outs).	-	-	-
11.	Number of cases rejected or kept out of analysis due to other reasons and justification thereof.	-	-	-
12.	Difficulties or problems or reasons of non-cooperation of subjects in giving information.	-	-	-

SELF SCORING : REPORTING

Section B

You may allot the numerical weights to each of your answers as follows :

Very clearly	Somewhat clearly	Not at all
2	1	0

To obtain the total score on "Reporting Stage" add up these scores over all the 12 items. You may then read the following qualitative description about your reporting.

Very Good Reporting	Good Reporting	Average Reporting	Poor Reporting	Very Poor Reporting
21 and above	15-19	10-14	5-9	0-4

An Overall Assessment

For an overall self-assessment of your sampling, use the following criteria. This includes section A and section B of the Scale. Add your scores on Section A and section B and then consult the following table :

	Very Good	**Good**	**Average**	**Poor**	**Very Poor**
Total Score :	41 and above	31-40	21-30	11-20	0-10

ADDITIONAL SCALES FOR GENERAL GUIDANCE ONLY
(No Scoring Suggested)

Section C

Systematic Sampling

1. If using systematic sampling did you ensure that there was no periodic effect or trend in the population or sampling frame ? Yes___ No___
2. If periodic effect was visible, did you arrange the sampling frame or stratify it ? Yes___ No___
3. Did you use the middle value or the randomly selected value from the first K elements as the starting point? Yes___ No___

4. After obtaining the sample, did you give a proper check by inspection whether it looked representative of the population ? Yes___ No___

Others

5. In using clusters, did you use all the elements found in the selected clusters ? Yes___ No___
6. In multi-stage sampling, did you use randomization at all stages ? Yes___ No___

Section D **Execution Stage**

The following points will be enlightening to the student. (No scoring suggested).

1. Have you been able to obtain data from all the elements included in the initial sample ? Yes___ No___
2. Were the persons contacted at the time of data collection, in possession of the information sought for? Yes___ No___
3. Did you make an all-out-effort to contact non-respondents and obtain data from them ? Yes___ No___
4. Did you substitute non-respondents by an equal group added through random selection ? Yes___ No___
5. Did you obtain information from a small group selected randomly out of non-respondents and compared the characteristics of non-respondents with those of respondents ? Yes___ No___

Post-stratification : Stratification which is carried out after the sample has been actually drawn or data collected.

Quasi-Periodicity : When period effect is visible only at some values of n.

Random Numbers : Numbers arranged through random selection.

Random Selection : Selection of units based on equal chance of selection to each unit.

Replicated Sampling : Sampling technique which uses a number of independent, self contained and adequate samples from the same population; useful for estimating sampling error.

Sample :A smaller portion taken, through some selected procedures, from a larger whole.

Sample conditioning : Sample sensitization due to repeated exposures.

Sample Mortality : Dropping out of the subjects from a sample on subsequent occasions of data collection or experiment.

Sampling Design : A broad strategy used for sampling; generally classified as probability, nonprobability and mixed.

Sampling Distribution : The distribution generated by a large number of statistics taken from a large number of random samples.

Sampling Error : The sampling variability generally accounted for and taken care of by probability theory.

Sampled Population : The population which has actually been sampled. (See target population for a distinction).

Selection Bias : It signifies that sample, for whatever reasons has not been drawn according to pre-arranged specifications.

Simple Random Sampling : Random selection done from the list of individual units and not of groups.

With replacement : Random selection in which the unit drawn each time is not put back in the aggregate so that the size of the aggregate remains constant at each draw of a unit.

Without replacement : Random selection in which the unit drawn each time is put back in the aggregate leading to the decrease by one unit in the size of the aggregate every time.

Sine Curve : A curve which changes in magnitude continuously and in direction, periodically.

Situation Sampling : The subjects are observed selectively in situations where the probability of target behaviour is high.

Statistical Samples : Samples based on probability sampling techniques.

Supply : See population.

Systematic Sampling : When units are selected from the list or frame through regular intervals as every 8th or every 10th unit etc.

Target Population : The population which we intended to sample or over which generalization of results was intended. (See experimentally accessible population for a distinction).

Technical Bias : A statistical effect which is the result of the functional form of the estimator not averaging overall possible samples to the true population value.

Time Sampling: A record of frequency of observable forms of occurrences during a number of definite time intervals systematically spaced is made.

Universe : See Population.

APPENDIX V

Table of t, for use in determining the significance of statistics

Example: When the *df* are 35 and $t=2.03$, the .05 in column 3 means that 5 times in 100 trials a divergence as large as that obtained may be expected in the positive *and* negative directions under the null hypothesis.

Degrees of Freedom	*Probability (P)* 0.10	0.05	0.02	0.01
(1)	(2)	(3)	(4)	(5)
1	$t=6.34$	$t=12.71$	$t=31.82$	$t=63.66$
2	2.92	4.30	6.96	9.92
3	2.35	3.18	4.54	5.84
4	2.13	2.78	3.75	4.60
5	2.02	2.57	3.36	4.03
6	1.94	2.45	3.14	3.71
7	1.90	2.36	3.00	3.50
8	1.86	2.31	2.90	3.36
9	1.83	2.26	2.82	3.25
10	1.81	2.23	2.76	3.17
11	1.80	2.20	2.72	3.11
12	1.78	2.18	2.68	3.06
13	1.77	2.16	2.65	3.01
14	1.76	2.14	2.62	2.98
15	1.75	2.13	2.60	2.95
16	1.75	2.12	2.58	2.92
17	1.74	2.11	2.57	2.90
18	1.73	2.10	2.55	2.88
19	1.73	2.09	2.54	2.86

(1)	(2)	(3)	(4)	(5)
20	1.72	2.09	2.53	2.84
21	1.72	2.08	2.52	2.83
22	1.72	2.07	2.51	2.82
23	1.71	2.07	2.50	2.81
24	1.71	2.06	2.49	2.80
25	1.71	2.06	2.48	2.79
26	1.71	2.06	2.48	2.78
27	1.70	2.05	2.47	2.77
28	1.70	2.05	2.47	2.76
29	1.70	2.04	2.46	2.76
30	1.70	2.04	2.46	2.75
35	1.69	2.03	2.44	2.72
40	1.68	2.02	2.42	2.71
45	1.68	2.02	2.41	2.69
50	1.68	2.01	2.40	2.68
60	1.67	2.00	2.39	2.66
70	1.67	2.00	2.38	2.65
80	1.66	1.99	2.38	2.64
90	1.66	1.99	2.37	2.63
100	1.66	1.98	2.36	2.63
125	1.66	1.98	2.36	2.62
150	1.66	1.98	2.35	2.61
200	1.65	1.97	2.35	2.60
300	1.65	1.97	2.34	2.59
400	1.65	1.97	2.34	2.59
500	1.65	1.96	2.33	2.59
1000	1.65	1.96	2.33	2.58
∞	1.65	1.96	2.33	2.58

Fractional parts of the total area (taken as 0.1000) under the normal probability curve, corresponding to distances on the base-line between the mean and successive points laid off from the mean in units of standard deviation

Example: Between the mean and a point 1.38 σ $\left(\frac{x}{\sigma}=1.38\right)$ are found 41.62% of the entire area under the curve.

$\frac{x}{\sigma}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	0000	0040	0080	0120	0160	0199	0239	0279	0319	0359
0.1	0398	0438	0478	0517	0557	0596	0636	0675	0714	0753
0.2	0793	0832	0871	0910	0948	0987	1026	1064	1103	1141
0.3	1179	1217	1255	1293	1331	1368	1406	1443	1480	1517
0.4	1554	1591	1628	1664	1700	1736	1772	1808	1844	1879
0.5	1915	1950	1985	2019	2054	2088	2123	2157	2190	2224
0.6	2257	2291	2324	2357	2389	2422	2454	2486	2517	2549

0.7	2580	2611	2642	2673	2704	2734	2764	2794	2823	2852
0.8	2881	2910	2939	2967	2995	3023	3051	3078	3106	3133
0.9	3159	3186	3212	3238	3264	3290	3315	3340	3365	3389
1.0	3413	3438	3461	3485	3508	3531	3554	3577	3599	3621
1.1	3643	3665	3686	3708	3729	3749	3770	3790	3810	3830
1.2	3849	3869	3888	3907	3925	3944	3962	3980	3997	4015
1.3	4032	4049	4066	4082	4099	4115	4131	4147	4162	4177
1.4	4192	4207	4222	4236	4251	4265	4279	4292	4306	4319
1.5	4332	4345	4357	4370	4383	4394	4406	4418	4429	4441
1.6	4452	4463	4474	4484	4495	4505	4515	4525	4535	4545
1.7	4554	4564	4573	4582	4591	4599	4608	4616	4625	4633
1.8	4641	4649	4656	4664	4671	4678	4686	4693	4699	4706
1.9	4713	4719	4726	4732	4738	4744	4750	4756	4761	4767
2.0	4772	4778	4783	4788	4793	4798	4803	4808	4812	4817
2.1	4821	4826	4830	4834	4838	4842	4846	4850	4854	4857
2.2	4861	4864	4868	4871	4875	4878	4881	4884	4887	4890
2.3	4893	4896	4898	4901	4904	4906	4909	4911	4913	4916
2.4	4918	4920	4922	4925	4927	4929	4931	4932	4934	4936
2.5	4938	4940	4941	4943	4945	4946	4948	4949	4951	4925

2.6	4953	4955	4956	4957	4959	4960	4961	4962	4963	4964
2.7	4965	4966	4967	4968	4969	4970	4971	4972	4973	4974
2.8	4974	4975	4976	4977	4977	4978	4979	4979	4980	4981
2.9	4981	4982	4982	4983	4984	4984	4985	4985	4986	4986
3.0	4986.5	4986.9	4987.4	4987.8	4988.2	4988.6	4988.9	4989.3	4989.7	4990.0
3.1	4990.3	4990.6	4991.0	4991.3	4991.6	4991.8	4992.1	4992.4	4992.6	4992.9
3.2	4993.129									
3.3	4995.166									
3.4	4996.631									
3.5	4997.674									
3.6	4998.409									
3.7	4998.922									
3.8	4999.277									
3.9	4999.519									
4.0	4999.683									
4.5	4999.966									
5.0	4999.997133									

TABLE OF RANDOM NUMBERS (8,000 NUMBERS)

First Thousand

	1–4	5–8	9–12	13–16	17–20	21–24	25–28	29–32	33–36	37–40
1	23 15	75 48	59 01	83 72	59 93	76 24	97 08	86 95	23 03	67 44
2	05 54	55 50	43 10	53 74	35 08	90 61	18 37	44 10	96 22	13 43
3	14 87	16 03	50 32	40 43	62 23	50 05	10 03	22 11	54 38	08 34
4	38 97	67 49	51 94	05 17	58 53	78 80	59 01	94 32	42 87	16 95
5	97 31	26 17	18 99	75 53	08 70	94 25	12 58	41 54	88 21	05 13
6	11 74	26 93	81 44	33 93	08 72	32 79	73 31	18 22	64 70	68 50
7	43 36	12 88	59 11	01 64	56 23	93 00	90 04	99 43	64 07	40 36
8	93 80	62 04	78 38	26 80	44 91	55 75	11 89	32 58	47 55	25 71
9	49 54	01 31	81 08	42 98	41 87	69 53	82 96	61 77	73 80	95 27
10	36 76	87 26	33 37	94 82	15 69	41 95	96 86	70 45	27 48	38 80
11	07 09	25 23	92 24	62 71	26 07	06 55	84 53	44 67	33 84	53 20
12	43 31	00 10	81 44	86 38	03 07	52 55	51 61	48 89	74 29	46 47
13	61 57	00 63	60 06	17 36	37 75	63 14	89 51	23 35	01 74	69 93
14	31 35	28 37	99 10	77 91	89 41	31 57	97 64	48 62	58 48	69 19
15	57 04	88 65	26 27	79 59	36 82	90 52	95 65	46 35	06 53	22 54
16	09 24	34 42	00 68	72 10	71 37	30 72	97 57	56 09	29 82	76 50
17	97 95	53 50	18 40	89 48	83 29	52 23	08 25	21 22	53 26	15 87
18	93 73	25 95	70 43	78 19	88 85	56 67	16 68	26 95	99 64	45 69
19	72 62	11 12	25 00	92 26	82 64	35 66	65 94	34 71	68 75	18 67
20	61 02	07 44	18 45	37 12	07 94	95 91	73 78	66 99	53 61	93 78
21	97 83	98 54	74 33	05 59	17 18	45 47	35 47	44 22	03 42	30 00
22	89 16	09 71	92 22	23 29	06 37	35 05	54 54	89 88	43 81	63 61
23	25 96	68 82	20 62	87 17	92 65	02 82	35 28	62 84	91 95	48 83
24	81 44	33 17	19 05	04 95	48 06	74 69	00 75	67 65	01 71	65 45
25	11 32	25 49	31 42	36 23	43 86	08 62	49 76	67 42	24 52	32 45

Second Thousand

	1–4	5–8	9–12	13–16	17–20	21–24	25–28	29–32	33–36	37–40
1	64 75	58 38	85 84	12 22	59 20	17 69	61 56	55 95	04 59	59 47
2	10 30	25 22	89 77	43 63	44 30	38 11	24 90	67 07	34 82	33 28
3	71 01	79 84	95 51	30 85	03 74	66 59	10 28	87 53	76 56	91 49
4	60 01	25 56	05 88	41 03	48 79	79 65	59 01	69 78	80 00	36 66
5	37 33	09 46	56 49	16 14	28 02	48 27	45 47	55 44	55 36	50 90
6	47 86	98 70	01 31	59 11	22 73	60 62	61 28	22 34	69 16	12 12
7	38 04	04 27	37 64	16 78	95 78	39 32	34 93	24 88	43 43	87 06
8	73 50	83 09	08 83	05 48	00 78	36 66	93 02	95 56	46 04	53 36
9	32 62	34 64	74 84	06 10	43 24	20 62	83 73	19 32	35 64	39 69
10	97 59	19 95	49 36	63 03	51 06	62 06	99 29	75 95	32 05	77 34
11	74 01	23 19	55 59	79 09	69 82	66 22	42 40	15 96	74 90	75 89
12	56 75	42 64	57 13	35 10	50 14	90 96	63 36	74 69	09 63	34 88
13	49 80	04 99	08 54	83 12	19 98	08 52	82 63	72 92	92 36	50 26
14	43 58	48 96	47 24	87 85	66 70	00 22	15 01	93 99	59 16	23 77
15	16 65	37 96	64 60	32 57	13 01	35 74	28 36	36 73	05 88	72 29
16	48 50	26 90	55 65	32 25	87 48	31 44	68 02	37 31	25 29	63 67
17	96 76	55 46	92 36	31 68	62 30	48 29	63 83	52 21	61 66	40 94
18	38 92	36 15	50 80	35 78	17 84	23 44	41 24	63 13	99 24	81 28
19	77 95	88 16	94 25	22 50	55 87	51 07	30 10	70 60	21 86	19 61
20	17 92	82 80	65 25	58 60	87 71	02 64	18 50	64 65	79 64	81 70
21	94 03	68 59	78 02	31 80	44 99	41 05	41 05	31 87	43 12	15 96
22	47 46	06 04	79 56	23 04	84 17	14 37	28 51	67 27	55 80	03 68
23	47 85	65 60	88 51	99 28	24 39	40 64	41 71	70 13	46 31	82 88
24	57 61	63 46	53 92	29 86	20 18	10 37	57 65	15 62	98 69	07 56
25	08 30	09 27	04 66	75 26	66 10	57 18	87 91	07 54	22 22	20 13

Source: Reproduced from M. G. Kendall and B. B. Smith, *Tables of Random Sampling Numbers*, Tracts for Computers XXIV (London: Cambridge University Press, 1939), pp. 2–5.

RANDOM NUMBERS

Third Thousand

	1–4	5–8	9–12	13–16	17–20	21–24	25–28	29–32	33–36	37–40
1	89 22	10 23	62 65	78 77	47 33	51 27	23 02	13 92	44 13	96 51
2	04 00	59 98	18 63	91 82	90 32	94 01	24 23	63 01	26 11	06 50
3	98 54	63 80	66 50	85 67	50 45	40 64	52 28	41 53	25 44	41 25
4	41 71	98 44	01 59	22 60	13 14	54 58	14 03	98 49	98 86	55 79
5	28 73	37 24	89 00	78 52	58 43	24 61	34 97	97 85	56 78	44 71
6	65 21	38 39	27 77	76 20	30 86	80 74	22 43	95 68	47 68	37 92
7	65 55	31 26	78 90	90 69	04 66	43 67	02 62	17 69	90 03	12 05
8	05 66	86 90	80 73	02 98	57 46	58 33	27 82	31 45	98 69	29 98
9	39 30	29 97	18 49	75 77	95 19	27 38	77 63	73 47	26 29	16 12
10	64 59	23 22	54 45	87 92	94 31	38 3[illegible]	00 59	81 18	06 78	71 37
11	07 51	34 87	92 47	31 48	36 60	68 90	70 53	36 82	57 99	15 82
12	86 59	36 85	01 56	63 89	98 00	82 83	93 51	48 56	54 10	72 32
13	83 73	52 25	99 97	97 78	12 48	36 83	89 95	60 32	41 06	76 14
14	08 59	52 18	26 54	65 50	82 04	87 99	01 70	33 56	25 80	53 84
15	41 27	32 71	49 44	29 36	94 58	16 82	86 39	62 15	86 43	54 31
16	00 47	37 59	08 56	23 81	22 42	72 63	17 63	14 47	25 20	63 47
17	86 13	15 37	89 81	38 30	78 68	89 13	29 61	82 07	00 98	64 32
18	33 84	97 83	59 04	40 20	35 86	03 17	68 86	63 08	01 82	25 46
19	61 87	04 16	57 07	46 80	86 12	98 08	39 73	49 20	77 54	50 91
20	43 89	86 59	23 25	07 88	61 29	78 49	19 76	53 91	50 08	07 86
21	29 93	93 91	23 04	54 84	59 85	60 95	20 66	41 28	72 64	64 73
22	38 50	58 55	55 14	38 85	50 77	18 65	79 48	87 67	83 17	08 19
23	31 82	43 84	31 67	12 52	55 11	72 04	41 15	62 53	27 98	22 68
24	91 43	00 37	67 13	56 11	55 97	06 75	09 25	52 02	39 13	87 53
25	38 63	56 89	76 25	49 89	75 26	96 45	80 38	05 04	11 66	35 14

Fourth Thousand

	1–4	5–8	9–12	13–16	17–20	21–24	25–28	29–32	33–36	37–40
1	02 49	05 41	22 27	94 43	93 64	04 23	07 20	74 11	67 95	40 82
2	11 96	73 64	69 60	62 78	37 01	09 25	33 02	08 01	38 53	74 82
3	48 25	68 34	65 49	69 92	40 79	05 40	33 51	54 39	61 30	31 36
4	27 24	67 30	80 21	48 12	35 36	04 88	18 99	77 49	48 49	30 71
5	32 53	27 72	65 72	43 07	07 22	86 52	91 84	57 92	65 71	00 11
6	66 75	79 89	55 92	37 59	34 31	43 20	45 58	25 45	44 36	92 65
7	11 26	63 45	45 76	50 59	77 46	34 66	82 69	99 26	74 29	75 16
8	17 87	23 91	42 45	56 18	01 46	93 13	74 89	24 64	25 75	92 84
9	62 56	13 03	65 03	40 81	47 54	51 79	80 81	33 61	01 09	77 30
10	62 79	63 07	79 35	49 77	05 01	30 10	50 81	33 00	99 79	19 70
11	75 51	02 17	71 04	33 93	36 60	42 75	76 22	23 87	56 54	84 68
12	87 43	90 16	91 63	51 72	65 90	44 43	70 72	17 98	70 63	90 32
13	97 74	20 26	21 10	74 87	88 03	38 33	76 52	26 92	14 95	90 51
14	98 81	10 60	01 21	57 10	28 75	21 82	88 39	12 85	18 86	16 24
15	51 26	40 18	52 64	60 79	25 53	29 00	42 66	95 78	58 36	29 98
16	40 23	99 33	76 10	41 96	86 10	49 12	00 29	41 80	03 59	93 17
17	26 93	65 91	86 51	66 72	76 45	46 32	94 46	81 94	19 06	66 47
18	88 50	21 17	16 98	29 94	09 74	42 39	46 22	00 69	09 48	16 46
19	63 49	93 80	93 25	59 36	19 95	79 86	78 05	69 01	02 33	83 74
20	36 37	98 12	06 03	31 77	87 10	73 82	83 10	83 60	50 94	40 91
21	93 80	12 23	22 47	47 95	70 17	59 33	43 06	47 43	06 12	66 60
22	29 85	68 71	20 56	31 15	00 53	25 36	58 12	65 22	41 40	24 31
23	97 72	08 79	31 88	26 51	30 50	71 01	71 51	77 06	95 79	29 19
24	85 23	70 91	05 74	60 14	63 77	59 93	81 56	47 34	17 79	27 53
25	75 74	67 52	68 31	72 79	57 73	72 36	48 73	24 36	87 90	68 02

RANDOM NUMBERS

Fifth Thousand

	1–4	5–8	9–12	13–16	17–20	21–24	25–28	29–32	33–36	37–40
1	29 93	50 69	71 63	17 55	25 79	10 47	88 93	79 61	42 82	13 63
2	15 11	40 71	26 51	89 07	77 87	75 51	01 31	03 42	94 24	81 11
3	03 87	04 32	25 10	58 98	76 29	22 03	99 41	24 38	12 76	50 22
4	79 39	03 91	88 40	75 64	52 69	65 95	92 06	40 14	28 42	29 60
5	30 03	50 69	15 79	19 65	44 28	64 81	95 23	14 48	72 18	15 94
6	29 03	99 98	61 28	75 97	98 02	68 53	13 91	98 38	13 72	43 73
7	78 19	60 81	08 24	10 74	97 77	09 59	94 35	69 84	82 09	49 56
8	15 84	78 54	93 91	44 29	13 51	80 13	07 37	52 21	53 91	09 86
9	36 61	46 22	48 49	19 49	72 09	92 58	79 20	53 41	02 18	00 64
10	40 54	95 48	84 91	46 54	38 62	35 54	14 44	66 88	89 47	41 80
11	40 87	80 89	97 14	28 60	99 82	90 30	87 80	07 51	58 71	66 58
12	10 22	94 92	82 41	17 33	14 68	59 45	51 87	56 08	90 80	66 60
13	15 91	87 67	87 30	62 42	59 28	44 12	42 50	88 31	13 77	16 14
14	13 40	31 87	96 49	90 99	44 04	64 97	94 14	62 18	15 59	83 35
15	66 52	39 45	96 74	90 89	02 71	10 00	99 86	48 17	64 06	89 09
16	91 66	53 64	69 68	34 31	78 70	25 97	50 46	62 21	27 25	06 20
17	67 41	58 75	15 08	20 77	37 29	73 20	15 75	93 96	91 76	96 99
18	76 52	79 69	96 23	72 43	34 48	63 39	23 23	94 60	88 79	06 17
19	19 81	54 77	89 74	34 81	71 47	10 95	43 43	55 81	19 45	44 07
20	25 59	25 35	87 76	38 47	25 75	84 34	76 89	18 05	73 95	72 22
21	55 90	24 55	39 63	64 63	16 09	95 99	98 28	87 40	66 66	66 92
22	02 47	05 83	76 79	79 42	24 82	42 42	39 61	62 47	49 11	72 64
23	18 63	05 32	63 13	31 99	76 19	35 85	91 23	50 14	63 28	86 59
24	89 67	33 82	30 16	06 39	20 07	59 50	33 84	02 76	45 03	33 33
25	62 98	66 73	64 06	59 51	74 27	84 62	31 45	65 82	86 05	73 00

Sixth Thousand

	1–4	5–8	9–12	13–16	17–20	21–24	25–28	29–32	33–36	37–40
1	27 50	13 05	46 34	63 85	87 60	35 55	05 67	88 15	47 00	50 92
2	02 31	57 57	62 98	41 09	66 01	69 88	92 83	35 70	76 59	02 58
3	37 43	12 83	66 39	77 33	63 26	53 99	48 65	23 06	94 29	53 04
4	83 56	65 54	19 33	35 42	92 12	37 14	70 75	18 58	98 57	12 52
5	06 81	56 27	49 32	12 42	92 42	05 96	82 94	70 25	45 49	18 16
6	39 15	03 60	15 56	73 16	48 74	50 27	43 42	58 36	73 16	39 90
7	84 45	71 93	10 27	15 83	84 20	57 42	41 28	42 06	15 90	70 47
8	82 47	05 77	06 89	47 13	92 85	60 12	32 89	25 22	42 38	87 37
9	98 04	06 70	24 21	69 02	65 42	55 33	11 95	72 35	73 23	57 26
10	18 33	49 04	14 33	48 50	15 64	58 26	14 91	46 02	72 13	48 62
11	33 92	19 93	38 27	43 40	27 72	79 74	86 57	41 83	58 71	56 99
12	48 66	74 30	44 81	06 80	29 09	50 31	69 61	24 64	28 89	97 79
13	85 85	07 54	21 50	31 80	10 19	56 65	82 52	26 58	55 12	26 34
14	08 27	08 08	35 87	96 57	33 12	01 77	52 76	09 89	71 12	17 69
15	59 61	22 14	26 09	96 75	17 94	51 08	41 91	45 94	80 48	59 92
16	17 45	77 79	31 66	36 54	92 85	65 60	53 98	63 50	11 20	96 63
17	11 26	37 08	07 71	95 95	39 75	92 48	99 78	23 33	19 56	06 57
18	48 08	13 98	16 52	41 15	73 96	32 55	03 12	38 30	88 77	17 03
19	76 27	72 22	99 61	72 15	00 25	21 54	47 79	18 41	58 50	57 66
20	98 89	22 25	72 92	53 55	07 98	66 71	53 29	61 71	56 96	41 78
21	88 69	61 63	01 67	61 88	58 79	35 65	08 45	63 38	69 86	79 47
22	12 58	13 75	80 98	01 35	91 16	18 36	90 54	99 17	68 36	85 06
23	08 86	96 36	14 09	43 85	51 20	65 18	06 40	52 17	48 10	68 97
24	33 81	05 51	32 48	60 12	32 44	08 12	89 00	98 82	79 17	97 22
25	05 15	99 28	87 15	07 08	66 92	53 81	69 42	02 27	65 33	57 69

RANDOM NUMBERS

Seventh Thousand

	1–4	5–8	9–12	13–16	17–20	21–24	25–28	29–32	33–36	37–40
1	80 30	23 64	67 96	21 33	36 90	03 91	69 33	90 13	34 48	02 19
2	61 29	89 61	32 08	12 62	26 08	42 00	31 73	31 30	30 61	34 11
3	23 33	61 01	02 21	11 81	51 32	36 10	23 74	50 31	90 11	73 52
4	94 21	32 92	93 50	72 67	23 20	74 59	30 30	48 66	75 32	27 97
5	87 61	92 69	01 60	28 79	74 76	86 06	39 29	73 85	03 27	50 57
6	37 56	19 18	03 42	86 03	85 74	44 81	86 45	71 16	13 52	35 56
7	64 86	66 31	55 04	88 40	10 30	84 38	06 13	58 83	62 04	63 52
8	22 69	58 45	49 23	09 81	98 84	05 04	75 99	27 70	72 79	32 19
9	23 22	14 22	64 90	10 26	74 23	53 91	27 73	78 19	92 43	68 10
10	42 38	59 64	72 96	46 57	89 67	22 81	94 56	69 84	18 31	06 39
11	17 18	01 34	10 98	37 48	93 86	88 59	69 53	78 86	37 26	85 48
12	39 45	69 53	94 89	58 97	29 33	29 19	50 94	80 57	31 99	38 91
13	43 18	11 42	56 19	48 44	45 02	84 29	01 78	65 77	76 84	88 85
14	59 44	06 45	68 55	16 65	66 13	38 00	95 76	50 67	67 65	18 83
15	01 50	34 32	38 00	37 57	47 82	66 59	19 50	87 14	35 59	79 47
16	79 14	60 35	47 95	90 71	31 03	85 37	38 70	34 16	64 55	66 49
17	01 56	63 68	80 26	14 97	23 88	59 22	82 39	70 83	48 34	46 48
18	25 76	18 71	29 25	15 51	92 96	01 01	28 18	03 35	11 10	27 84
19	23 52	10 83	45 06	49 85	35 45	84 08	81 13	52 57	21 23	67 02
20	91 64	08 64	25 74	16 10	97 31	10 27	24 48	89 06	42 81	29 10
21	80 86	07 27	26 70	08 65	85 20	31 23	28 99	39 63	32 03	71 91
22	31 71	37 60	95 60	94 95	54 45	27 97	03 67	30 54	86 04	12 41
23	05 83	50 36	09 04	39 15	66 55	80 36	39 71	24 10	62 22	21 53
24	98 70	02 90	30 63	62 59	26 04	97 20	00 91	28 80	40 23	09 91
25	82 79	35 45	64 53	93 24	86 55	48 72	18 57	05 79	20 09	31 46

Eighth Thousand

	1–4	5–8	9–12	13–16	17–20	21–24	25–28	29–32	33–36	37–40
1	37 52	49 55	40 65	27 61	08 59	91 23	26 18	95 04	98 20	99 52
2	48 16	69 65	69 02	08 83	08 83	68 37	00 96	13 59	12 16	17 93
3	50 43	06 59	56 53	30 61	40 21	29 06	49 60	90 38	11 43	19 25
4	89 31	62 79	45 73	71 72	77 11	28 80	72 35	75 77	24 72	98 43
5	63 29	90 61	86 39	07 38	38 85	77 06	10 23	30 84	07 95	30 76
6	71 68	93 94	08 72	36 27	85 89	40 59	83 37	93 85	73 97	84 05
7	05 06	96 63	58 24	05 95	56 64	77 53	85 64	15 95	93 91	59 03
8	03 35	58 95	46 44	25 70	31 66	01 05	44 44	62 91	36 31	45 04
9	13 04	57 67	74 77	53 35	93 51	82 83	27 38	63 16	04 48	75 23
10	49 96	43 94	56 04	02 79	55 78	01 44	75 26	85 54	01 81	32 82
11	24 36	24 08	44 77	57 07	54 41	04 56	09 44	30 58	25 45	37 56
12	55 19	97 20	01 11	47 45	79 79	06 72	12 81	86 97	54 09	06 53
13	02 28	54 60	28 35	32 94	36 74	51 63	96 90	04 13	30 43	10 14
14	90 50	13 78	22 20	37 56	97 95	49 95	91 15	52 73	12 93	78 94
15	33 71	32 43	29 58	47 38	39 96	67 51	64 47	49 91	64 58	93 07
16	70 58	28 49	54 32	97 70	27 81	64 69	71 52	02 56	61 37	04 58
17	09 68	96 10	57 78	85 00	89 81	98 30	19 40	76 28	62 99	99 83
18	19 36	60 85	35 04	12 87	83 88	66 54	32 00	30 20	05 30	42 63
19	04 75	44 49	64 26	51 46	80 50	53 91	00 55	67 36	68 66	08 29
20	79 83	32 39	46 77	56 83	42 21	60 03	14 47	07 01	66 85	49 22
21	80 99	42 43	08 58	54 41	98 05	54 39	34 42	97 47	38 35	59 40
22	48 83	64 99	86 94	48 78	79 20	62 23	56 45	92 65	56 36	83 02
23	28 45	35 85	22 20	13 01	73 96	70 05	84 50	68 59	96 58	16 63
24	52 07	63 15	82 30	66 23	14 26	66 61	17 80	41 97	40 27	24 80
25	39 14	52 18	35 87	48 55	48 81	03 11	26 99	03 80	08 86	50 42

Index

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